UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Regulatory Impact Analysis for the New Source Performance Standards for the Synthetic Organic Chemical Manufacturing Industry and National Emission Standards for Hazardous Air Pollutants for the Synthetic Organic Chemical Manufacturing Industry and Group I & II Polymers and Resins Industry

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

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1 EXECUTIVE SUMMARY

1.1 Background

The U.S Environmental Protection Agency (EPA) is proposing amendments to the National Emissions Standards for Hazardous Air Pollutants (NESHAP) for subparts (40 CFR part 63, subparts F, G, H, & I) that apply to synthetic organic chemical manufacturing industry (SOCMI) and to equipment leaks from certain non-SOCMI processes located at chemical plants. These four NESHAP are more commonly referred to together as the Hazardous Organic NESHAP (HON). The HON contains maximum achievable control technology (MACT) standards for HAP from heat exchange systems, process vents, storage vessels, transfer racks, wastewater, and equipment leaks at chemical plants that are major sources of HAP producing SOCMI chemicals (*e.g.*, bulk commodity chemicals) and for equipment leaks for certain non-SOCMI chemical processes. The EPA is proposing to revise NESHAP requirements for storage tanks, loading operations, and equipment leaks to reflect cost-effective developments in practices, process, or controls of hazardous air pollutants (HAP).

The EPA is also proposing amendments to the NESHAP for subparts (40 CFR part 63, subparts U and W) that apply to the polymers and resins (P&R) Group I and II industries. P&R Group I refers to major source facilities that produce certain elastomers and regulates HAP emissions from nine different source categories. P&R Group I contains MACT standards for HAP from storage tanks, process vents, equipment leaks, wastewater systems, and heat exchange systems. P&R Group II applies to existing and new epoxy resins and non-nylon polyamides production operations that are located at major sources. Similarly, P&R Group II contains MACT standards for HAP from storage tanks, process vents, equipment leaks, and wastewater systems.

The EPA is also proposing New Source Performance Standards (NSPS) to reflect best system of emissions reduction for four SOCMI NSPS subparts (40 CFR part 60, subparts III, NNN, RRR, & VV) for emissions of volatile organic compound (VOC) from SOCMI air oxidation unit processes, SOCMI distillation operations, SOCMI reactor processes, and equipment leaks located at SOCMI sources. The proposal also includes revisions related to emissions during periods of startup, shutdown, and malfunction (SSM); additional requirements for electronic reporting of performance test results, performance evaluation reports, and compliance reports; revisions to monitoring and operating requirements for control devices; and other minor technical improvements.

1.1.1 NESHAP for subparts F, G, H, I, U, & W

The statutory authority for the proposed NESHAP amendments is provided by sections 112 and 301 of the Clean Air Act (CAA), as amended (42 U.S.C. 7401 *et seq*.). Section 112 of the CAA establishes a two-stage regulatory process to develop standards for emissions of HAP from stationary sources. Generally, the first stage involves establishing technology-based standards and the second stage involves evaluating those standards that are based on maximum achievable control technology (MACT) to determine whether additional standards are needed to address any remaining risk associated with HAP emissions. This second stage is commonly referred to as the "residual risk review." In addition to the residual risk review, the CAA also requires the EPA to review standards set under CAA section 112 every 8 years and revise the standards as necessary taking into account any "developments in practices, processes, or control technologies." This review is commonly referred to as the "technology review," and is the subject of this proposal.

In the first stage of the CAA section 112 standard setting process, the EPA promulgates technology-based standards under CAA section 112(d) for categories of sources identified as emitting one or more of the HAP listed in CAA section 112(b). Sources of HAP emissions are either major sources or area sources, and CAA section 112 establishes different requirements for major source standards and area source standards. "Major sources" are those that emit or have the potential to emit 10 tons per year (tpy) or more of a single HAP or 25 tpy or more of any combination of HAP. All other sources are "area sources." For major sources, CAA section 112(d)(2) provides that the technology-based NESHAP must reflect the maximum degree of emission reductions of HAP achievable (after considering cost, energy requirements, and non-air quality health and environmental impacts). These standards are commonly referred to as MACT standards. CAA section 112(d)(3) also establishes a minimum control level for MACT standards, known as the MACT "floor." In certain instances, as provided in CAA section 112(h), the EPA may set work practice standards in lieu of numerical emission standards. The EPA must also consider control options that are more stringent than the floor. Standards more stringent than the floor are commonly referred to as beyond-the-floor standards. For area sources, CAA section

112(d)(5) allows the EPA to set standards based on generally available control technologies or management practices (GACT standards) in lieu of MACT standards. For categories of major sources and any area source categories subject to MACT standards, the second stage in standard-setting focuses on identifying and addressing any remaining (*i.e.,* "residual") risk pursuant to CAA section 112(f) and concurrently conducting a technology review pursuant to CAA section 112(d)(6). MACT standards were finalized for the HON source category in 1994. The residual risk and technology review (RTR) was finalized in 2006.

The MACT standards for P&R Group I (40 CFR part 63, subpart U) were initially promulgated in 1996. Most recently, the agency conducted its RTR of the Group I NESHAP in 2008, for four source categories, and in 2011, for the remaining source categories. The MACT standards for P&R Group II (40 CFR part 63, subpart W) were initially promulgated in 1995, with the agency most recently conducting its RTR of the Group II NESHAP in 2008.

The source categories that are the subject of this proposal include the HON source category (and whose facilities, sources and processes we often refer to as "HON facilities," "HON sources," and "HON processes") and several Polymers and Resins Production source categories covered in P&R Group I and II (see section II.B of the preamble for detailed information about the source categories). The North American Industry Classification System (NAICS) code for SOCMI facilities begins with 325, for P&R I is 325212, and for P&R II is 325211, but is not exhaustive of affective facilities.

As defined in the Initial List of Categories of Sources Under Section 112(c)(1) of the CAA Amendments of 1990 (see 57 FR 31576, July 16, 1992) and Documentation for Developing the Initial Source Category List, Final Report (see EPA-450/3-91-030, July 1992), the SOCMI source category is any facility engaged in "manufacturing processes that produce one or more of the chemicals [listed] that either (1) use an organic HAP as a reactant or (2) produce an organic HAP as a product, co-product, by-product, or isolated intermediate." Related chemicals for the HON and P&R Group I and II source categories are listed in the Industry Profile section of this report.

1.1.2 NSPS subparts III, NNN, RRR, & VVb

The EPA's authority for the NSPS proposal is CAA section 111, which governs the establishment of standards of performance for stationary sources. CAA section 111(b)(1)(A) requires the EPA Administrator to list categories of stationary sources that in the Administrator's judgement cause or contribute significantly to air pollution that may reasonably be anticipated to endanger public health or welfare. The EPA must then issue performance standards for new (and modified or reconstructed) sources in each source category pursuant to CAA section 111(b)(1)(B). These standards are referred to as new source performance standards, or NSPS. The EPA has the authority under CAA section 111(b) to define the scope of the source categories, determine the pollutants for which standards should be developed, set the emission level of the standards, and distinguish among classes, type, and sizes within categories in establishing the standards.

Section 111(b)(1)(B) of the CAA requires the EPA to "at least every 8 years review and, if appropriate, revise" new source performance standards. Section 111(a)(1) of the CAA provides that performance standards are to "reflect the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction and any non-air quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated." We refer to this level of control as the best system of emission reduction or "BSER." The term "standard of performance" in CAA 111(a)(1) makes clear that the EPA is to determine both the BSER for the regulated sources in the source category and the degree of emission limitation achievable through application of the BSER. The EPA must then, under CAA section 111(b)(1)(B), promulgate standards of performance for new sources that reflect that level of stringency. These subparts were originally promulgated pursuant to CAA section 111(b) on June 29, 1990 (subparts III and NNN); August 31, 1993 (subpart RRR); and November 16, 2007 (subpart VV).

The emission sources covered by these NSPS subparts are comparable (and in many instances are the same) as HON sources subject to our standards for process vents (NSPS III, NNN, & RRR) and equipment leaks (NSPS VV), though regulated pollutants and definitions of what constitutes an affected source/affected facility are different between the NESHAP and NSPS.

1.2 Market Failure

Many regulations are promulgated to correct market failures, which otherwise lead to a suboptimal allocation of resources within a market. Air quality and pollution control regulations address "negative externalities" whereby the market does not internalize the full opportunity cost of production borne by society as public goods such as air quality are unpriced.

While recognizing that the optimal social level of pollution may not be zero, HAP and VOC emissions impose costs on society, such as negative health and welfare impacts, that are not reflected in the market price of the goods produced through the polluting process. For this regulatory action the goods produced are chemical products (*e.g.*, butadiene, ethylene oxide). If processes of producing butadiene or ethylene oxide yield pollution emitted into the atmosphere, the social costs imposed by the pollution will not be borne by the polluting firms but rather by society as a whole. Thus, the producers are imposing a negative externality, or a social cost from these emissions, on society. The equilibrium market price of chemical products such as butadiene or ethylene oxide may fail to incorporate the full opportunity cost to society of consuming the chemical product. Consequently, absent a regulation or some other action to limit such emissions, producers will not internalize the negative externality of pollution due to emissions and social costs will be higher as a result. This proposed regulation will serve to address this market failure by causing affected producers to begin internalizing the negative externality associated with HAP and other emissions also affected by this proposal such as VOC.

1.3 Results for Proposed Action

1.3.1 Baseline for the Regulation

The impacts of regulatory actions are evaluated relative to a baseline that represents to the extent possible the world without the regulatory action. In this RIA, the EPA presents analysis results for the proposed amendments to the HON, P&R I, P&R II, and several proposed NSPS (VVb, IIIa, NNNa, RRRa). Throughout this document, the EPA focuses the analysis on the proposed requirements that result in quantifiable compliance cost or emissions changes compared to the baseline as identified above. For each rule and most emissions sources, EPA assumed each facility achieved emissions control meeting current standards, and estimated emissions reductions and cost relative to this baseline. The baseline does include what are termed as “excess emissions” reflecting current emissions from the SOCMI and thus are pertinent to estimates of emission reductions for the proposed HON and P&R I and I amendments and our estimates of emission reductions are calculated relative to these “excess emissions.” We calculate cost and emissions reductions relative to the baseline for the period 2024-2038. This time frame spans the time period from when the NSPSs take effective (under the assumption that the proposed action is finalized in 2024) through the lifetime of the typical capital equipment (15 years) expected to be installed as a result of the proposed NESHAP and NSPS amendments if finalized.

The summaries of impact results below are for the proposed options. In accordance with OMB Circular A-4 (US OMB, 2003),[1] we also present impact results for a more stringent and less stringent set of options as defined by that circular, which is the guidance for regulatory analysis to be followed by Federal agencies preparing an RIA such as this one. These alternatives are defined in Chapter 6, where results are presented for these options along with those for the proposed option.

1.3.1.1 Overview of Costs and Benefits for the Proposed Options

The proposed amendments to the HON constitute a significant regulatory action. This action is significant, under section 3(f)(1) of Executive Order 12866, because it likely to have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or state, local, or tribal governments or communities. The EPA monetized the projected benefits of reducing VOC emissions in terms of the value of avoided ozone-attributable deaths and illnesses, both short- (ST) and long-term (LT). The EPA also monetized the benefits and disbenefits from changes in emissions of climate pollutants such as carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4).

Table 1-1 also presents projected benefits, climate disbenefits (including benefits), compliance costs, and net benefits, and HAP emission reductions from the proposed amendments to the HON. The projected climate disbenefits are caused by increased electricity usage for the controls included in the cost analysis for the proposed HON. Projected climate benefits are

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[1] U.S. Office of Management and Budget. Circular A-4, “Regulatory Analysis.” September 17, 2003. Available at https://www.whitehouse.gov/wp-content/uploads/legacy_drupal_files/omb/circulars/A4/a-4.pdf.

caused by reduction of CH_4 emissions from control of flares. Certain control options analyzed in this RIA lead to chemical product recovery, which has been monetized as product recovery credits. Net compliance costs are calculated as total compliance costs minus product recovery credits. For a discussion of product recovery, see Chapter 3. Monetized net benefits are projected to be negative using short- and long-term estimates of ozone health benefits and both 3 percent and 7 percent social discount rates, and including the climate benefits and disbenefits estimated at 3 percent. Further, while benefits from HAP reductions and VOC reductions outside of the ozone season have not been monetized for this proposed action, EPA expects these benefits are positive. Also monetized for this proposed action are climate benefits from emission reductions of CH_4 and the climate disbenefits from increases in CO_2 and N_2O emissions resulting from increased electricity usage associated with additional emissions controls. The unmonetized effects include disbenefits from secondary emissions increases of CO_2 resulting from increased electricity usage associated with additional emissions controls. As mentioned earlier, we calculate cost and emissions reductions relative to the baseline for the period 2024-2038, with costs discounted to 2023.

Table 1-1: Monetized Benefits, Compliance Costs, Emission Reductions and Net Benefits for Proposed Amendments to the HON (dollars in million 2021$[2])[a]

	3 Percent Discount Rate		7 Percent Discount Rate	
	PV	**EAV**	**PV**	**EAV**
Monetized Health Benefits[b]	$78 and $690	$6.5 and $58	$53 and $470	$5.8 and $51
Climate Disbenefits (3%)[c]	$(25.4)	$(2.1)	$(25.4)	$(2.1)
Net Compliance Costs[d]	$1,385	$116	$922	$101
Compliance Costs	*$1,393*	*$117*	*$927.7*	*$102*
Value of Product Recovery	*$8*	*$1*	*$5*	*$0.8*
Net Benefits	$(1,280) and $(670)	$(107) and $(56)	$(844) and $(427)	$(93) and $(48)
Nonmonetized Benefits	5,726 tons of HAP emission reductions. Health effects from reduced exposure to ethylene oxide, chloroprene, benzene, 1,3-butadiene, vinyl chloride, ethylene dichloride, chlorine, maleicanhydride, and acrolein			

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

[b] Monetized benefits include ozone related health benefits associated with reductions in VOC emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent for

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[2] When necessary, dollar figures in this RIA have been converted to 2021$ using the annual GDP Implicit Price Deflator values in the U.S. Bureau of Economic Analysis' (BEA) NIPA Table 1.1.9 found at found at <https://fred.stlouisfed.org/release/tables?rid=53&eid=41158>.

benefits. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates. Benefits from HAP reductions and VOC reductions outside of the ozone season remain unmonetized and are thus not reflected in the table. The unmonetized effects also include disbenefits resulting from the secondary impact of an increase in CO emissions.

[c] Monetized climate benefits and disbenefits are based on changes (increases) in CO_2 and N_2O emissions and decreases in CH_4 emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC-GHG) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the benefits and disbenefits (and net benefits) associated with the model average SC-GHG at a 3 percent discount rate, but the Agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits and disbenefits calculated using all four SC-GHG estimates; Please see Table 4-11 for the full range of SC-GHG estimates. As discussed in Chapter 4, a consideration of climate benefits and disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. A number in parentheses denotes a negative value. Negative climate disbenefits is a positive value.

[d] Net compliance costs are the engineering control costs minus the value of recovered product. A negative net compliance costs occurs when the value of the recovered product exceeds the compliance costs.

1.3.1.2 Overview of Costs and Benefits for the Proposed P&R I

The proposed amendments to P&R I do not constitute an economically significant regulatory action. This action is a significant regulatory action Table 1-2 presents projected monetized health benefits, climate disbenefits (inclusive of climate benefits as with the HON summary impacts table above), compliance costs, and HAP emissions reductions from the proposed amendments to P&R I. There are projected climate benefits caused by CH_4 emission reductions, and projected climate disbenefits caused by CO_2 and N_2O emissions increases. While benefits from HAP reductions and VOC reductions outside of the ozone season have not been monetized for this action, EPA expects these benefits are positive. As mentioned earlier, we calculate cost and emissions reductions relative to the baseline for the period 2024-2038, with cost discounted to 2023.

Table 1-2: Monetized Benefits, Compliance Costs, and Net Benefits for Proposed Amendments to P&R I (dollars in million 2021$)[a]

	3 Percent Discount Rate		7 Percent Discount Rate	
	PV	EAV	PV	EAV
Health Benefits[b]	$2.6 and $23	$0.22 and $1.9	$1.8 and $16	$0.19 and $1.7
Climate Disbenefits[c]	$40.5	$3.4	$40.5	$3.4
Net Compliance Costs[d]	$121	$10	$78	$8.6
Compliance Costs	*$122*	*$10.2*	*$79*	*$8.7*
Value of Product Recovery	*1.0*	*$0.2*	*$1*	*$0.1*
Net Benefits	($159) and $(139)	($13) and $(12)	($116) and $(103)	($12) and $(10)
Nonmonetized Benefits				

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

[b] Monetized benefits include ozone related health benefits associated with reductions in VOC emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent for benefits. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates. Benefits from HAP reductions and VOC reductions outside of the ozone season remain unmonetized and are thus not reflected in the table. The unmonetized effects also include disbenefits resulting from the secondary impact of an increase in CO emissions.

[c] Monetized climate benefits and disbenefits are based on changes (increases) in CO_2 and N_2O emissions and decreases in CH_4 emissions are calculated using four different estimates of the social cost of each greenhouse gas (SC-GHG) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the benefits and disbenefits (and net benefits) associated with the model average SC-GHG at a 3 percent discount rate, but the Agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits and disbenefits calculated using all four SC-GHG estimates. Please see Table 4-11 for the full range of SC-GHG estimates. As discussed in Chapter 4, a consideration of climate benefits and disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. A number in parentheses denotes a negative value. Negative climate disbenefits is a positive value.

[d] Net compliance costs are the engineering control costs minus the value of recovered product. A negative net compliance costs occurs when the value of the recovered product exceeds the compliance costs.

1.3.1.3 Overview of Costs and Benefits for the Proposed P&R II

The proposed amendments to P&R II do not constitute an economically significant regulatory action. This action is a significant regulatory action Table 1-3 presents projected monetized health benefits, and compliance costs, from the proposed amendments to P&R II. There are minimal emission reductions from the proposed amendments (less than 1 ton per year of HAP and VOC). There are no projected climate benefits and disbenefits from these proposed amendments. While benefits from HAP reductions and VOC reductions outside of the ozone season have not been monetized for this action, EPA expects these benefits are positive. As mentioned earlier, we calculate cost and emissions reductions relative to the baseline for the period 2024-2038.

Table 1-3: Monetized Benefits, Compliance Costs, and Net Benefits for Proposed Amendments to P&R II (dollars in million 2021$)[a]

	3 Percent Discount Rate		7 Percent Discount Rate	
	PV	**EAV**	**PV**	**EAV**
Monetized Health Benefits[b]	$0	$0	$0	$0
Net Compliance Costs[c]	$4	$0.4	$3	$0.4
Compliance Costs	*$4*	*$0.4*	*$3*	*$0.4*
Value of Product Recovery	*$0*	*$0*	*$0*	*$0.0*
Net Benefits	$ (4)	$ (0.4)	$ (3)	$ (0.4)
Nonmonetized Benefits	1 ton/year of HAP emission reduction. Reduced health exposure to epichlorohydrin			

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

[b] There are no monetized health benefits for this proposed rule. There are also no climate benefits or disbenefits for this proposed rule. The unmonetized effects also include disbenefits resulting from the secondary impact of an increase in CO emissions.

[c] Net compliance costs are the engineering control costs minus the value of recovered product. A negative net compliance costs occurs when the value of the recovered product exceeds the compliance costs. For this proposal, there is no product recovery.

1.3.1.4 Overview of Costs and Benefits for the Proposed Subpart VVb NSPS

The proposed amendments to the subpart VVb NSPS do not constitute an economically significant regulatory action. This action is a significant regulatory action Table 1-4 presents projected monetized health benefits, and compliance costs (with and without product recovery), from the proposed amendments to subpart VVb. There are no projected climate benefits or disbenefits. While benefits from VOC reductions outside of the ozone season have not been monetized for this action, EPA expects these benefits are positive. As mentioned earlier, we calculate cost and emissions reductions relative to the baseline for the period 2024-2038.

Table 1-4: Monetized Benefits, Compliance Costs, and Net Benefits for Proposed NSPS subpart VVb (dollars in million 2021$)[a]

	3 Percent Discount Rate		7 Percent Discount Rate	
	PV	**EAV**	**PV**	**EAV**
Monetized Health Benefits[b]	$1.2 and $11	$0.10 and $0.93	$0.85 and $7.5	$0.09 and $0.82
Net Compliance Costs[c]	$11.0	$0.9	$8.0	$0.9
Compliance Costs	*$13.3*	*$1.1*	*$9.7*	*$1.1*
Value of Product Recovery	*$2.3*	*$0.2*	*$1.7*	*$0.2*
Net Benefits	$(9.8) and $0	$(0.8) and $0.03	$(7.2) and $(0.5)	$(0.8) and $(0.1)

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

[b] Monetized benefits include ozone related health benefits associated with reductions in VOC emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent for benefits. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates. Benefits from HAP reductions and VOC reductions outside of the ozone season remain unmonetized and are thus not reflected in the table. There are no climate benefits or disbenefits associated with this proposed NSPS.

[c] Net compliance costs are the engineering control costs minus the value of recovered product. A negative net compliance costs occurs when the value of the recovered product exceeds the compliance costs.

1.3.1.5 Overview of Costs and Benefits for the Proposed Subparts IIIa, NNNa, and RRRa

The proposed amendments to the subparts IIIa, NNNa, and RRRa, do not constitute an economically significant regulatory action. This action is a significant regulatory action Table 1-5 presents projected monetized health benefits, climate disbenefits (inclusive of climate benefits as with the HON summary impacts table above), and compliance costs (with and without product recovery), from the proposed amendments to these three NSPS. There are projected climate benefits caused by CH_4 emission reductions, and projected climate disbenefits caused by CO_2 and N_2O emissions increases. While benefits from HAP reductions and VOC reductions outside of the ozone season have not been monetized for this action, EPA expects these benefits are positive. As mentioned earlier, we calculate cost and emissions reductions relative to the baseline for the period 2024-2038.

Table 1-5: Monetized Benefits, Compliance Costs, and Net Benefits for Proposed Amendments to Subparts IIIa, NNNa, and RRRa (dollars in million 2021$)[a]

	3 Percent Discount Rate		7 Percent Discount Rate	
	PV	**EAV**	**PV**	**EAV**
Monetized Health Benefits[b]	$4.6 and $41	$0.39 and $3.5	$3.2 and $28	$0.35 and $3.0
Climate Disbenefits[c]	$(6.8)	$(0.57)	$(6.8)	$(0.57)
Net Compliance Costs[d]	$56	$4.7	$40	$4.4
Compliance Costs	*$56*	*$4.7*	*$40*	*$4.4*
Value of Product Recovery	*$0*	*$0*	*$0*	*$0*
Net Benefits	($45) and $(8)	($3.7) and $(0.6)	($30) and $(5)	($3.5) and $(0.8)

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

[b] Monetized benefits include ozone related health benefits associated with reductions in VOC emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent for benefits. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. Benefits from HAP reductions and VOC reductions outside of the ozone season remain unmonetized and are thus not reflected in the table. The estimates do not represent lower- and upper-bound estimates. The unmonetized effects also include disbenefits resulting from the secondary impact of an increase in CO emissions.

[c] Monetized climate benefits and disbenefits are based on changes (increases) in CO_2 and N_2O emissions and decreases in CH_4 emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC-GHG) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the benefits and disbenefits (and net benefits) associated with the model average SC-GHG at a 3 percent discount rate, but the Agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits and disbenefits calculated using all four SC-GHG estimates. Please see Table 4-11 for the full range of SC-GHG estimates. As discussed in Chapter 4, a consideration of climate benefits and disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. A parenthesis around a number denotes it as having a negative value). Negative climate disbenefits is a positive value.

[d] Net compliance costs are the engineering control costs minus the value of recovered product. A negative net compliance costs occurs when the value of the recovered product exceeds the compliance costs.

1.3.1.6 Overview of Costs and Benefits for All Rules

Table 1-6 presents the cumulative projected monetized health benefits, climate disbenefits (inclusive of climate benefits as with the HON summary impacts table above), and compliance costs (net of product recovery). Cumulatively, there are 6,053 tons per year of HAP emission reductions and 23,515 tons per year of VOC emission reductions, and Table 3-25 contains those reductions both cumulatively and by proposed rule. There are also emission increases (per year) in criteria pollutants of 17.4 tons of fine particulate matter (PM2.5), 349 tons of nitrogen oxides (NOx), and 1.37 tons of sulfur dioxide (SO2) due to additional energy usage from the controls applied in the proposal cost analysis. Finally, there are emission increases per year of 741,102 tons of carbon dioxide (CO2), 6.86 tons of nitrous oxide (N2O), and emission decreases per year of 22,951 tons of methane (CH4). Table 3-26 contains the changes in emissions other than for HAP and VOC. Thus, there are projected climate benefits caused by CH_4 emission reductions, and projected climate disbenefits caused by CO_2 and N_2O emissions increases. While benefits from HAP reductions and VOC reductions outside of the ozone season have not been monetized for this action, EPA expects these benefits are positive. As mentioned earlier, we calculate cost and emissions reductions relative to the baseline for the period 2024-2038, discounted to 2023

Table 1-6: Monetized Benefits, Compliance Costs, Emission Reductions, and Net Benefits for Proposed Amendments to HON, P&R I, and P&R II NESHAP and Proposed Amendments to subpart VVb, IIIa, NNNa, and RRRa NSPS (dollars in million 2021\$)[a]

	3 Percent Discount Rate		7 Percent Discount Rate	
	PV	**EAV**	**PV**	**EAV**
Monetized Health Benefits[b]	\$81 and \$730	\$6.8 and \$61	\$56 and \$490	\$6.1 and \$54
Climate Disbenefits[c]	\$8.2	\$0.7	\$8.2	\$0.7
Net Compliance Costs[d]	\$1,579	\$132	\$1,052	\$116
Compliance Costs	*\$1,590*	*\$133.4*	*\$1,059.7*	*\$117.1*
Value of Product Recovery	*\$11*	*\$1.4*	*\$7.7*	*\$1.1*
Net Benefits	(\$1,506) and \$(857)	(\$126) and \$(71)	(\$1,100) and \$(570)	(\$110) and \$(63)
Nonmonetized Benefits	6,053 tons/year of HAP Health effects of reduced exposure to ethylene oxide, chloroprene, benzene, 1,3-butadiene, vinyl chloride, ethylene dichloride, chlorine, maleic anhydride and acrolein			

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

[b] Monetized benefits include ozone related health benefits associated with reductions in VOC emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent for benefits. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. Benefits from HAP reductions and VOC reductions outside of the ozone season remain unmonetized and are thus not reflected in the table. The estimates do not represent lower- and upper-bound estimates. The unmonetized effects also include disbenefits resulting from the secondary impact of an increase in CO emissions.

[c] Monetized climate benefits and disbenefits are based on changes (increases) in CO_2 and N_2O emissions and decreases in CH_4 emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC-GHG) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the benefits and disbenefits (and net benefits) associated with the model average SC-GHG at a 3 percent discount rate, but the Agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits and disbenefits

calculated using all four SC-GHG estimates. Please see Table 4-11 for the full range of SC-GHG estimates. As discussed in Chapter 4, a consideration of climate benefits and disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. A number in parentheses denotes a negative value. Negative climate disbenefits is a positive value.

[d] Net compliance costs are the engineering control costs minus the value of recovered product. A negative net compliance costs occurs when the value of the recovered product exceeds the compliance costs.

1.4 Organization of the Report

The remainder of this report details the methodology and the results of the RIA. Chapter 2 presents a profile of the SOCMI and P&R Group I and II industries, which also cover the industries with sources affected by the NSPS amendments included in this rulemaking. Chapter 3 describes emissions, emissions control options, and engineering costs. Chapter 4 presents the benefits analysis, including the monetized health benefits from VOC and other emission reductions, a qualitative discussion of the unmonetized benefits associated with HAP emissions reductions and the monetized benefits associated with climate emissions decreases (CH_4) and disbenefits associated with climate (CO_2 and N_2O) emissions increases. Chapter 5 presents analyses of economic impacts, impacts on small businesses, and a narrow analysis of employment impacts. The economic impacts include estimates of price and output changes in response to the costs of different proposed rules. The small business impact analysis includes estimates of annual cost to sales calculations for affected small business, and concludes that no proposed rule in this rulemaking will have a significant impact on a substantial number of small entities (or SISNOSE). Chapter 6 presents a comparison of the benefits and costs. Chapter 7 contains the references for this RIA.

2 INDUSTRY PROFILE

This chapter will provide a profile of SOCMI and P&R Group I and II industries affected under this combined rulemaking. While there is overlap between these rules, affected facilities and area sources are distinct enough that this chapter will provide separate sub-chapters for SOCMI and P&R Group I and II below. EPA constructed facility lists for these rules based on data from the 2017 National Emissions Inventory (NEI). However, instances where facility-specific data was not available in the in the 2017 NEI, more recent data was collected from the 2018 NEI or recent state submittals to the Emissions Inventory System (EIS).[3] The construction of the facility list is described in the preamble for the proposed action.

2.1 SOCMI Industry Profile

The synthetic organic chemical manufacturing industry (SOCMI) consists of about 400 chemicals. A U.S. Environmental Protection Agency (EPA) regulatory impact analysis from 1994 identified approximately 30 key chemicals that represent a large portion of output from the industry.[4] This profile revisits these chemicals and their feedstocks, listed in Table 2-1, to provide an updated industry profile.

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[3] Revenue and employment information was collected through manual search of D&B Hoover's database in 2022.

[4] U.S. EPA. Regulatory Impact Analysis for the National Emissions Standards for Hazardous Air Pollutants for Source Categories: Organic Hazardous Air Pollutants from the Synthetic Organic Chemical Manufacturing Industry and Other Process Subject to the Negotiated Regulation for Equipment Leaks. EPA-453/R-94-019. March 1994.

Table 2-1: Select SOCMI Chemicals by Feedstock*

Benzene	**Methane**
Styrene-Butadiene Rubber	Formaldehyde
Cyclohexylamine	Chloroform
Hydroquinone	Methyl Tertiary Butyl Ether
Styrene	Methyl Chloride
Acetone	**Ethylene**
Bisphenol-A	Butadiene
Propylene Glycol	Polybutadiene
Toluene	Ethylene Dichloride
Benzoic Acid	Ethylene Oxide
Xylene	Ethylene Glycol
Terephthalic Acid	Triethylene Glycol
Phthalic Anhydride	**Propylene**
Naphthalene	Acrylonitrile
Ether	**Butylene**

*This list of chemicals is from the HON Regulatory Impact Analysis (EPA, 1994)

Synthetic organic chemicals (SOCs) are derived from chemical reactions using feedstocks containing carbon, such as fossil fuels like oil and natural gas. Supply relies on the market prices of these feedstocks, but advancements in technology and energy efficiency have resulted in large production economies of scale. The main source of demand for SOCs is plastics manufacturers. In addition, there is demand from a multitude of other industries, including but not limited to rubber, paints, adhesives, food, and pesticides (Barnicki, 2017).

Existing overall market and industry research for SOCs is scarce. The SOC market in the United States was valued at $168 billion in 2022 (IBISWorld). SOCMI is a subsector of the much larger organic chemicals market, which includes natural organic chemicals. Seven of the eight major feedstocks (excluding naphthalene) belong to a subset of SOCs called petrochemicals, named for their derivation from crude oil and natural gas, in addition to other possible sources like coal or vegetable oils. Petrochemicals can be used to make a variety of products, including rubber, fuel, cleaning agents, and plastics (ScienceDirect, 2022).

The global petrochemicals market size value was $556.1 billion in 2021. An industry report from Grand View Research prepared in 2021 forecasts the petrochemical market to grow at a compound annual growth rate (CAGR) of 6.2% from 2022 to 2030. The growth in demand is expected to result from an increase in demand for downstream products from various end-use industries such as construction, pharmaceuticals, and automotive. Because crude oil is the basic raw material in production, crude oil price volatility significantly affects production and the final costs of petrochemical products (Grand View Research, 2021).

Ethylene had the largest revenue share for the petrochemical industry, over 40.0% in 2021. The large revenue share from the ethylene market is due to the wide variety of everyday products that use this chemical. Ethylene is developed into four different compounds that produce many products, including:

- Polyethylene (Plastics) – used to make food packaging, bottles, bags, and other plastics-based goods.
- Ethylene Oxide / Ethylene Glycol – becomes polyester for textiles, as well as antifreeze for airplane engines and wings.
- Ethylene Dichloride – this, in turn, becomes a vinyl product used in PVC pipes, siding, medical devices, and clothing.
- Styrene – synthetic rubber found in tires, as well as foam insulation

Ongoing industrialization and growing automotive and packaging sectors in emerging economies such as India, Brazil, Vietnam, and Thailand are forecasted to drive up demand for ethylene products. Butadiene was the second-largest product segment in 2021. Methanol is predicted to have the fastest revenue growth, a CAGR of 7.8%, over the forecast period. Methanol is a chemical building block for hundreds of everyday products, including plastics, paints, car parts and construction materials. Methanol also is a clean energy resource used to fuel cars, trucks, buses, ships, fuel cells, boilers and cook stoves. There is increasing demand for methanol from industries such as construction, paints and adhesives, pharmaceuticals, plastics, and automotive (OEC, 2022a).

The Asia Pacific region has a volume share of over 50.0% of the petrochemicals industry. Increasing natural gas exploration activities in the United States and Canada will grow the petrochemicals market in North America over the coming years; additionally, this provides an opportunity for substituting some raw materials with natural gas in the production of several petrochemicals (Grand View Research, 2021).

In 2018, total global trade of petrochemicals was valued at $123 billion. From 2017 to 2018, exports of petrochemicals worldwide grew by 42.5%, from $86.5 billion. The top exporters in 2018 were Saudi Arabia ($17.0 billion), the United States ($12.8 billion), Germany ($9.8 billion), Belgium ($7.5 billion), and Thailand ($7.0 billion). Of United States exports, 26.4% went to Mexico, 21.2% to Canada, and 8.97% to China.

The top importers of petrochemicals were China ($19.4 billion), Germany ($7.24 billion), the United States ($6.39 billion), Italy ($4.76 billion), and Turkey ($4.19 billion). The United States imported 42% of its petrochemicals from Canada, 19.9% from Mexico, 6.17% from Germany, and the remainder largely from Asia (OEC, 2022a). Hence, the U.S. was a net exporter in 2018 with exports at nearly twice the size of imports in monetary terms.

The SOCMI industry is marginally competitive because companies continuously participate in mergers, acquisitions, and joint ventures with governments and other stakeholders. For example, Chevron Phillips Chemical and Qatar Petroleum announced a joint venture on a chemical plant in Qatar in 2019. As of 2019, LyondellBasell Industries N.V., a multinational company founded in the Netherlands, held the largest market share of 4% (ChemAnalyst, 2021). That same year, LyondellBasell and the China Petroleum & Chemical Corporation (Sinopec) formed a joint venture to produce propylene oxide and styrene monomer in China (Novicio, 2021).

As more natural gas is tapped in the United States and prices decrease (as of 2021), the United States has become increasingly cost competitive. More U.S. firms are keeping production in the United States instead of outsourcing to foreign countries or using imported oil. For example, firms like Dow Chemical, Exxon Mobile, Chevron Phillips Chemical, and Royal Dutch Shell have all invested in new ethylene plants and projects in the United States over the last several years, causing a significant increase in ethylene production (Pearce, 2014). As of 2021, the United States held approximately 40% of the world’s ethane petrochemical production capacity (Novicio, 2021). In 2022, the world gas supply chain was disrupted by the war in Ukraine. However, because of limited domestic LNG shipping capacity, U.S. gas prices are likely to remain below global market prices, continuing to give the U.S. petrochemical manufactures a slight competitive advantage.

Table 2-2 summarizes the top ten globally produced SOCs by total market value, with U.S. trade statistics and their common use cases. U.S. exports and imports include their global rank (in parentheses) if they fall within the top five global importers and exporters of that commodity.

Table 2-2: Top 10 Globally Produced SOCs by Total Market Value

Chemical	Total Production (year)	Total Global Trade	U.S. Exports (global rank)	U.S. Imports (global rank)	Uses
Xylene	$178.45B (2021)	$2.18B	$49.9M	$26.1M	Production of drugs and plastics; solvents; intermediate for dyes and organic synthesis, especially isophthalic acid; insecticides; aviation fuel; manufacturing of polyester and alkyl resins; fibers, films, and resins; herbicide; production of polyester polyurethanes used in paints and sealants
Propylene	$96.47B (2021)	$5.59B	$559M (3)	$142M	Plastics and carpet fibers; chemical intermediate for the manufacture of acetone, isopropylbenzene, isopropanol, isopropyl halides, propylene oxide, acrylonitrile, and cumene; production of gasoline or used as a fuel in oil refineries
Ethylene	$81.34B (2020)	$4.95B	$401M (5)	$191K	Oxyethylene welding; chemical manufacturing; fruit ripening; general anesthetic; common ingredient in household products, such as plastics, certain foods, and some detergents; manufacturing ethylene oxide; polyethylene for plastics, alcohol, mustard gas, and other organics
Benzene	$68.3B (2021)	$4.75B	$38.7M	$632M (2)	Solvent for chemical synthesis, constituent in motor fuels, detergents, explosives, pharmaceuticals, dyestuffs

Chemical	Total Production (year)	Total Global Trade	U.S. Exports (global rank)	U.S. Imports (global rank)	Uses
Terephthalic Acid	$49.2B (2020)	$4.12B	$23.3M	$414M (2)	Feedstock for the production of polyesters, such as PET; wool processing; production of plastic films and sheets; added to certain poultry feeds and antibiotics to increase effectiveness
Styrene	$34.23B (2022)	$7.22B	$1.65B (1)	$387M (5)	Polystyrene production (low cost, low friction plastic used in packaging, textiles, and construction)
Toluene	$21.15B (2021)	$1.62B	$40.2M	$133M (4)	Solvent in aviation and automotive fuels; chemical production; production of paints, paint thinners, fingernail polish, lacquers, adhesives, and rubber; printing and leather tanning processes; production of benzene, TNT, nylon, plastics, and polyurethanes
Bisphenol-A	$16.23B (2020)	$1.46B	$2.88M	$37.2M	Production of polycarbonate plastics and epoxy resins
Acrylonitrile	$12.9B (2020)	$2.03B	$584M (1)	$9.26M	Manufacture of acrylic and modacrylic fibers, production of plastics
Styrene-Butadiene Rubber	$10.24B (2020)	$4.49B	$259M	$472M (2)	Rubber products such as gloves, tires, and adhesives

2.1.1 Oil and Gas Sectors and SOCMI

Olefins[5] (ethylene, propylene and butadiene, and butenes) are derived from both natural gas and petroleum. The aromatics (benzene, toluene, and xylenes) are derived from petroleum and, minorly, coal. Whether natural gas fractions or petroleum are used for olefins varies throughout the world depending on the availability of natural gas and demand for gasoline. Both

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[5] Olefins are a class of chemicals made up of hydrogen and carbon with one or more pairs of carbon atoms linked by a double bond. They are used as building block materials for products such as plastics, detergents, and adhesives.

light and heavy naphthas[6] are petroleum fractions that can be used to make olefins. But they can also be used to make gasoline (Wittcoff, 2012).

In the United States, approximately 95% of all organic chemicals by weight are derivatives of petroleum and natural gas. There has historically been ample natural gas supply in the United States, resulting in cheaper processing of ethane and propane, as opposed to more expensive petroleum cracking processes[7] for liquids, and naphtha.

In addition, the United States has had an ample supply of propylene, because it is produced in steam cracking for other products and because catalytic cracking is a required process in the gasoline industry. The propylene industry is based on this reaction that occurs in the catalytic cracking process, yielding billions of pounds of product generated (Wittcoff, 2012).

Because of low-cost and high-domestic availability in the United States, there is an incentive for U.S. manufacturers to use natural gas as a feedstock, replacing heavier liquid gases such as naphtha. Changes in incentives for raw material use also affects byproduct production prices, because byproducts, such as butadiene resulting from ethylene cracking, could be affected by new technologies or production processes. Most prices for raw materials will respond in the same direction as the changes in price for natural gas. Material costs respond in the opposite direction of natural gas prices, while costs for byproducts respond in tandem with natural gas prices (DeRosa, 2015).

The petroleum industry is often divided between upstream and downstream activities. Upstream activities include exploration, production and transportation of crude oil and gas transformation into final products through refineries. Downstream activities include processing of crude oil in refineries, as well as the distribution and marketing activities for related oil-derived products (Santos Manzano, 2005).

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[6] Naphthas are any of various volatile, highly flammable liquid hydrocarbon mixtures used chiefly as solvents and diluents and as raw materials for conversion to gasoline.

[7] Cracking is the process by which heavy hydrocarbon molecules are broken up into lighter molecules by means of heat and usually pressure and sometimes catalysts. Cracking is the most important process for the commercial production of gasoline and diesel fuel.

The chemical industry is considered an upstream industry, because it purchases raw materials such as petroleum, natural gas, coal, and metallic or nonmetallic minerals and does not usually sell these products to final consumers. About one-fifth of materials are sold to other firms in the chemical industry for additional processing, and then the remainder is sold to other industries to assist in product manufacturing or services (Wittcoff, 2012).

It is often the case that oil refineries become integrated with nearby petrochemicals plants. This integration allows both plants to exchange supply chain streams. The petrochemical facility receives streams of raw materials from the oil refinery, and the refinery receives back streams from the petrochemical plant that can be used again for petroleum products (*e.g.*, gasoline blending). The petrochemical plants produce high-value products like ethylene, propylene, styrene, butadiene, and benzene. Furthermore, these base petrochemicals can be transformed further into other products like plastics, polyvinyl chloride (PVC), polystyrene, polyethylene, polypropylene, elastomers, and aromatics-based products.[10]

The petrochemical industry is significantly affected by the volatility of crude oil prices because oil is a basic raw material used for product manufacturing. Both price and supply volatility have affected the production costs of petrochemicals, increasing the overall cost of the production process. Related factors, such as the increase in consumers in developed and developing regions who are concerned about environmental sustainability, as well as price changes in raw materials used in petrochemical creation, are additional factors that influence the market (Santos Manzano, 2005).

2.1.2 SOCMI Supply Chain Disruptions

Supply chain disruptions can happen either upstream or downstream, but it is worth noting that within the chemical industry upstream suppliers tend to be of greater concern to overall business continuity (Kotzé, 2017). Analyzing chemical supply chains is often a difficult task because multiple infrastructure systems support related supply chains.

Geopolitically, a “risk-free” trading perspective is one of domestic production as a sourcing option. From the geopolitical supply risk indicator work cited in Helbig (2016), the political stability of a trading partner country is weighted by its share of the sum of total import flows and domestic production all together. The identification of geopolitical risk factors such as political stability, absence of violence or terrorism, domestic availability, and share of import flows within a trading country often corresponds to different supply chain points that are based on international trade patterns, where supply concentration or political instability result in market price volatility (Helbig, 2016).

In addition to geopolitical risk factors, natural hazard disruptions affect many facets of the petrochemical supply chain, resulting in longer recovery periods before production continues (Stamber, 2011). As an example, Hurricane Ike in 2008 damaged readily available utilities, raw materials, logistics, and production sites that negatively affected efforts to begin operations post-disaster. These disruptions often ripple both up and down the supply chains, affecting recovery.

Increases in the use of different feedstocks, such as natural gas, can also provide insights into production and market cost effects that can occur in chemical supply chains.[7] In the United States, incentives for natural gas use affect price patterns for byproducts of petrochemicals, such as benzene, butadiene, and propylene. The cost of benzene, a byproduct of naphtha, stays relatively constant during this feedstock change. The cost of butadiene, in contrast, increases as natural gas prices decrease. Butadiene is a byproduct of ethylene cracking streams, and as feedstocks change to exclude naphtha from cracking procedures through the integration of ethane cracking streams, industry costs are minimized, and butadiene prices rise.[9]

On a global scale, COVID-19 and the Russia-Ukraine war have both affected oil and chemical market prices. Continuing trends remain to affect the industry through changing societal concerns for environmental issues, preferences for sustainable products, accelerated energy transition, capacity demand and growth, and the continuous adoption of digitization. These trends, while not all expected to continue after the COVID-19 pandemic, have disrupted pertinent supply chains. The first quarter of 2020 saw an unanticipated downturn for the oil, gas, and chemical industries as oversupply issues were exacerbated, and global oil price collapses narrowed domestic feedstock cost advantages that petrochemical companies in the United States benefitted from (Deloitte Insights, 2022).

While the COVID-19 crisis may have abated somewhat worldwide since 2020, the Russia-Ukraine war has also been a key factor in oil price changes in 2022. Consumer demand reduced as oil prices increased, thus eroding profitability in the chemical industry. China has surpassed the United States as the world's largest chemical market; it now accounts for more than 45% of worldwide chemical sales. Some European chemical companies are also feeling this pressure, as they expect a drop in 2022 profit (Stokes, 2022).

2.1.3 Ethylene

Ethylene is a valuable chemical product in both the U.S. and the world. It is the third most valuable synthetic organic chemical product as of 2020 with $81.34 billion in revenue worldwide. U.S. exports of ethylene were $401 million as of 2020. Ethylene by-products are valuable due to their many important uses in common products. One of those by-products is ethylene oxide. Ethylene oxide is used in the synthesis of ethylene glycol, as a sterilizing agent for medical supplies and foods, as a fumigant, and as an insecticide.[8]

Due to the EPA's 2016 updated Integrated Risk Information System (IRIS) inhalation unit risk estimate (URE) for ethylene oxide, which shows that ethylene oxide is significantly more toxic than previously known (*i.e.*, resulting in an inhalation URE 60 times greater than the previous URE over a 70-year lifetime), the EPA is concerned about the cancer risks posed from the SOCMI (*i.e.,* HON) source category. The EPA's 2006 risk and technology review (RTR) did not have the benefit of this updated URE at the time it was conducted, but if it had, it would have necessarily resulted in different conclusions about risk acceptability and the HON's provision of an ample margin of safety to protect public health.

Similarly, for chloroprene, when the EPA conducted the first residual risk assessment for the HON and neoprene production source categories, there was no suitable EPA IRIS inhalation URE for chloroprene and, therefore, no cancer risk was attributed to chloroprene emissions in either of those risks reviews. The EPA's 2006 and 2008 RTRs did not have the benefit of this new URE at the time they were conducted, but if they had would have necessarily resulted in different conclusions about risk acceptability and P&R I's provision of an ample margin of safety to protect public health. Consequently, this industry profile examines ethylene broadly, a

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[8] Observatory of Economic Complexity (2022). "Oxirane (ethylene oxide)." https://oec.world/en/profile/hs/oxirane-ethylene-oxide

key feedstock of ethylene oxide and chloroprene. Butadiene is also examined and is a coproduct of ethylene production.

Ethylene is a hydrocarbon gas that is produced by some fruits and vegetables through natural processes. Ethylene is a by-product during the decomposition of organic material. It is a common ingredient in various household products, including plastic, certain foods, and some detergents. In 2020, ethylene was the world's 596th most traded product, with a total trade of $4.95 billion. Between 2019 and 2020 the exports of ethylene decreased by 27.8%, from $6.85 billion to $4.95 billion, in part due to the Covid-19 pandemic. Trade in ethylene represents 0.03% of total world trade (OEC, 2022b).

Ethylene is used to produce fabricated plastics, antifreeze, and fibers. It is also used in the process to produce ethylene oxide and to produce polyethylene for plastics, alcohol, mustard gas, and other organics (National Center for Biotechnology Information, 2022a). Ethylene is a product of steam cracking of petroleum hydrocarbons. Multiple feedstocks produce ethylene, including ethane, propane, butanes, naphthas, and gas oils. Naphthas are the primary raw material used in Western Europe and Japan, accounting for more than three-fourths of ethylene produced. Ethane is the primary feedstock in the United States, followed by propane, naphthas, gas oils, and butane. Small amounts of ethylene are recovered from other feedstocks, such as retrograde-field condensates and refinery waste gases. Dehydration of ethanol is the third commercial process for producing ethylene (National Center for Biotechnology Information, 2022a).

In 2020, the top exporters of ethylene were the Netherlands ($682 million), South Korea ($608 million), the United Kingdom ($587 million), and the United States ($401 million). Of U.S.'s ethylene exports, 38.5% were exported to Taiwan, 34.2% to China, 9.78% to Indonesia, 9.03% to Belgium. In the United States from 2019 to 2020, the export value was $401 million, an increase of 82.6% from a 2018 to 2019 value of $219 million (Fernández, Ethylene Prices Globally 2022, 2022).

In 2020, the top importers of ethylene were China ($1.35 billion), Belgium ($921 million), Indonesia ($552 million), Germany ($432 million), and Sweden ($360 million). In the United States from 2019 to 2020, the import value was $190,000, an increase of 135.4% from a 2018 to 2019 value of $81,000 (Fernández, Ethylene Prices Globally 2022, 2022).

The average price of ethylene worldwide was approximately $697 per metric ton in 2020. By July 2021, the average price for the year had risen to $1,014 per metric ton (see Figure 2-1), 45% higher than the previous year. “The global production capacity of ethylene is expected to grow from approximately 200 million tons in 2020 to some 300 million tons by 2025” (Fernández, Ethylene Prices Globally 2022, 2022).

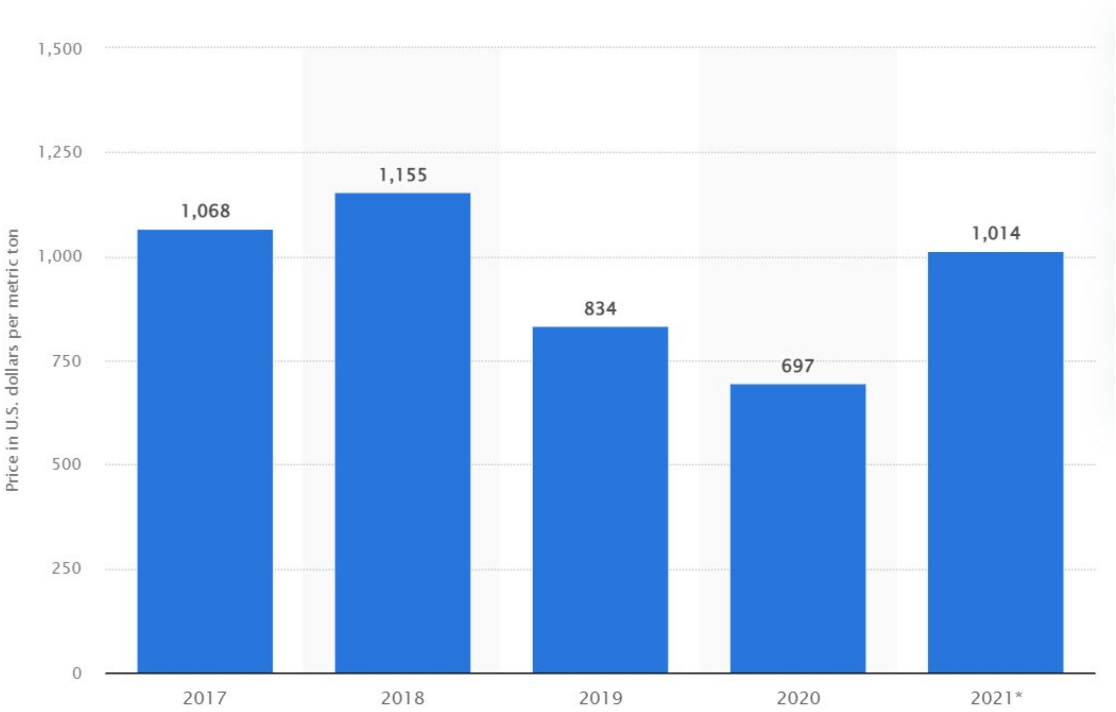

Figure 2-1 Global Price of Ethylene (USD$/metric ton)

The global ethylene market is expected to grow from $81.34 billion in 2020 to $161.61 billion by 2028 at a CAGR of 8.3% during the forecast period of 2021 to 2028. The increased use of coal as a feedstock for producing ethylene and the rising demand for ethylene products in the construction industry are some of the factors fueling the ethylene market (Global Newswire, 2022).

Key companies in the global ethylene market are Saudi Basic Industries Corp., Exxon Mobil Corporation, Dow DuPont Inc., Royal Dutch Shell plc, China Petroleum & Chemical Corporation, Chevron Phillips Chemical Company LLC, LyondellBasell Industries N.V., The National Petrochemical Company, BASF SE, and Lonza Group, among others (Polaris Market Research, 2021).

2.1.3.1 Butadiene

Butadiene (1,3-Butadiene) is a synthetic, colorless gas that is basically insoluble in water but soluble in ethanol, ether, acetone, and benzene (National Center for Biotechnology Information, 2022b). Butadiene emits acrid fumes and is flammable when it is heated. When butadiene is oxidized, it can form explosive peroxides. Butadiene rubber is a primary material used in the production of car tires, gaskets, hoses, synthetic brushes, and synthetic carpets (National Center for Biotechnology Information, 2022b).

Butadiene is used as a monomer in the manufacturing process of many different types of polymers and copolymers. It is also used as a chemical intermediate in the production of industrial chemicals. Butadiene is manufactured primarily as a co-product of ethylene production from steam cracking in the United States, Western Europe, and Japan (National Center for Biotechnology Information, 2022b).

The global 1,3 butadiene market is expected to reach $33.01 billion by 2020. Growing demand for tires of all types "on account of an upturn in the automotive industry (particularly in China, India, and Brazil) is expected to remain a key driving factor for the global market" (Grand View Research, 2015).

As shown in Figure 2-2, the price of butadiene has decreased since 2017. At the start of the first quarter of 2022, prices remained low initially. "During January (2022), the prices dropped significantly by 10% as compared to last quarter of 2021. The initial decline in the prices was attributed to the abundant supplies and weak trading activities. Demand from downstream Styrene Butadiene Rubber (SBR) and Acrylonitrile Butadiene Styrene (ABS) plastic has remained bearish in the region. As the upstream Crude and Natural gas prices rallied upwards by the mid quarter, the Butadiene sentiments shifted marginally towards the upward side in USA. Korea, a major exporter of Butadiene exported the product in USA at sky high values due to soaring freight charges. The prices of Butadiene FD Texas were last assessed at USD1445/MT during March, 2022 in United States. Moreover, robust demand from downstream derivatives SBR and PBR kept the Butadiene prices on the higher side" (Fernández, 2021).

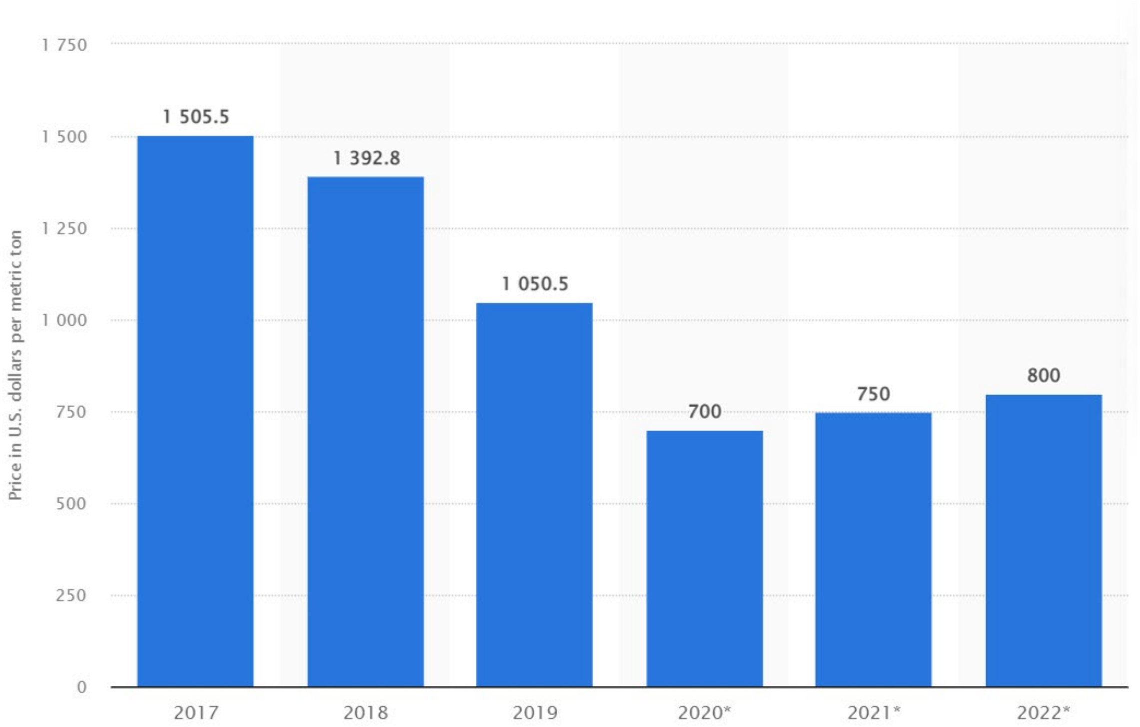

Figure 2-2: Global Price of Butadiene from 2017 to 2019 with Estimated Figures for 2020 to 2022

2.1.3.2 Ethylene Oxide

Ethylene oxide is a colorless, flammable, toxic gaseous cyclic ether with a sweet ether-like smell (National Center for Biotechnology Information, 2022c). "Ethylene oxide is used especially in the synthesis of ethylene glycol and as a sterilizing agent for medical supplies and foods, as a fumigant and as an insecticide" (OEC, 2022c).

Exposure to ethylene oxide can be highly irritating to the eyes, skin, and respiratory tract, inducing nausea and vomiting and causing central nervous system depression (National Center for Biotechnology Information, 2022c). It is also mutagenic in humans, and chronic exposure is associated with an increased risk of leukemia, stomach cancer, pancreatic cancer, and non-Hodgkin lymphoma (OEC, 2022c).

Nearly all production of ethylene oxide in the United States uses the direct vapor phase oxidation process. "This process oxidizes ethylene with air or oxygen in the presence of a silver catalyst to produce ethylene oxide" (OEC, 2022c).

In 2020, the top exporters of oxirane (ethylene oxide) were Germany ($161 million), the Netherlands ($123 million), Belgium ($40 million), France ($28.9 million), and Russia ($15.8

million) (OEC, 2022c). In the United States from 2019 to 2020, the export value was $8.82 million, a decrease of 14.7% from a 2018 to 2019 value of $10.3 million.

In 2020, the top importers of oxirane (ethylene oxide) were Belgium ($88.9 million), Italy ($80.4 million), Germany ($73.6 million), France ($40.5 million), and the United Kingdom ($19.2 million). In the United States from 2019 to 2020, the import value was $68,900, an increase of 975% from a 2018 to 2019 value of $6,410.

Prices of nonyl phenol ethoxylates (upstream product of ethylene oxide) in the United States grew as over 2021 and the first quarter of 2022 "in response to the higher Ethylene Oxide feedstock prices and outstretching demand" (ChemAnalyst, 2022).

Supply shocks can have a significant impact on the relatively concentrated market. For example, "the curtailed operations in ExxonMobil's Baytown refinery following an explosion in late December 2021 have continued to create a supply deficiency of upstream olefins and consequently caused its prices to gain significant numbers. The high upstream pricing, which got transferred to its downstream Ethylene Oxide, weighed on the input cost of Nonylphenol Ethoxylates. Prompting the manufacturers for a price increase, thus, the Nonylphenol Ethoxylates US discussions reached $1923/MT FOB[9] Gulf Coast in the quarter ending March 2022" (U.S. EPA, 2016).

2.2 P&R Groups I and II

This sub-chapter focuses on the industries of the Polymers and Resin Group I and II NESHAP. The economic and financial information in this chapter characterizes the conditions in these industries which are likely to determine the nature of economic impacts associated with the implementation of the NESHAP.

Section 2.2 provides an overview of the Group I synthetic rubber industries. Section 2.2.1 details the production processes, properties, and unique market characteristics for each elastomer. Section 2.3 provides an overview of the industries covered by Polymers and Resin

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[9] "MT FOB" stands for "metric ton free on board." This refers to the price of one metric ton of a chemical product, which includes the cost of the product and the cost of loading it onto a vessel for transportation. "FOB" means that the cost of transportation from the point of origin to the port of shipment is included in the price, but the cost of shipping the product to its final destination is not included.

Group II. Sections 2.3.1 describes epoxy resins and non-nylon polyamides production and their markets.

Figure 2-3 provides a geographic overview of where Group I and Group II facilities affected by this rule are located across the U.S. Group I facilities are clustered in the South with most based in Louisiana and Texas and others spread across the Midwest. There are fewer Group II facilities affected under this rule; four facilities are distributed in the South, while one is located in Oregon.

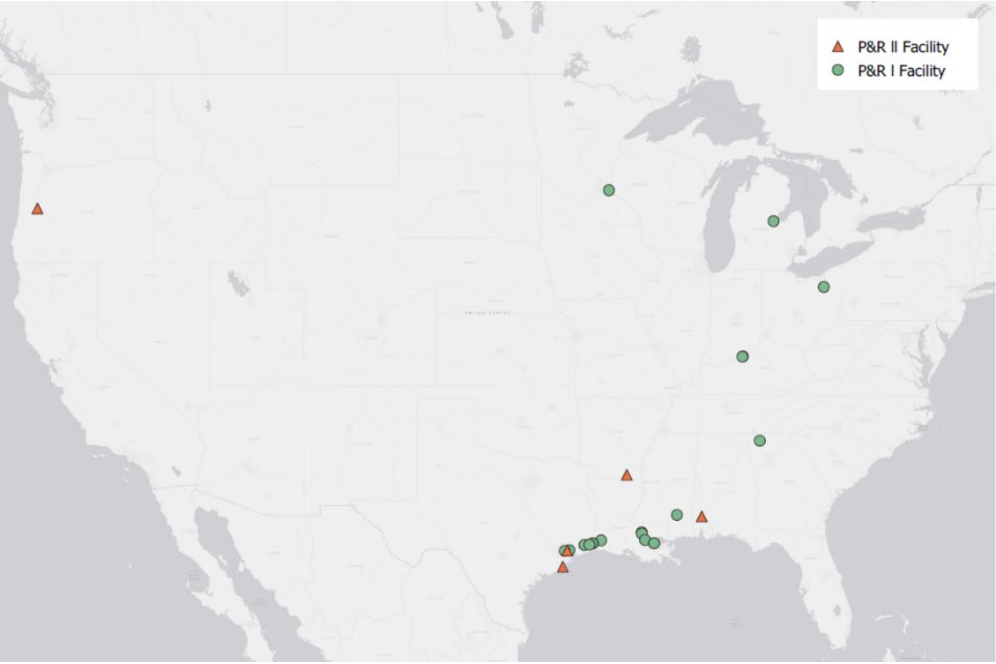

Figure 2-3: P&R Group I and II Facilities Map

2.2.1 Group I Industry Profile

This section reviews the organization, processes, and products of the affected synthetic rubber industries. The affected firms are further identified by size and economic impacts in a later section. Each facility considered in the production of Group I elastomers is categorized by a North American Industry Classification System (NAICS) code. This code is a "standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy" and used for defining industries. Across the identified facilities in Group I, there are four unique NAICS industries with varying representation in the associated NESHAP and the U.S. economy. [10] Table 2-3 provides 2017 data for these industries in the U.S. economy, not only considering facilities directly impacted by this rulemaking.[11] Data on industries is sourced from the quinquennial Economic Census which last occurred in 2017.

Table 2-3: Polymers and Resin Group I Industries

NAICS	Name of Industry	Number of Facilities (% of Total Facilities)	Total Revenue in 2017 (in Billions)	Total Employment in 2017
325110	Petrochemical Manufacturing	1 (5.6%)	$52.97	9,369
325211	Plastics Material and Resin Manufacturing	3 (16.7%)	$89.52	75,998
325212	Synthetic Rubber Manufacturing	13 (72.2%)	$8.39	9,661
325998	All Other Miscellaneous Chemical Product and Preparation Manufacturing	1 (5.6%)	$21.85	36,900

2.2.2 Industry Organization of Group I Industries

This section provides information on the structure of the covered synthetic rubber industries and the characteristics of the market organization of the affected Group I industries. This is an attempt to characterize the impacts regulation can have in more detailed terms.

Table 2-4 shows how the firms in each product category can be characterized by market concentration: the market share percentage for the 50 largest firms of the affected industries by NAICS code. The standard economic framework is that the higher the market concentration, the more that changes in input price caused by regulation will lead to rises in output price. An example of this is presented in a 2018 report by Abdela and Steinbaum, which concludes that there is a market concentration problem in U.S. production, generally (Abdela, 2018). This assumption has been criticized by Newmark, who argues that "[P]rice-concentration studies are severely flawed. In industries in which sellers compete on quality and amenities, a positive price-concentration relation could result, not from coordinated effects, but from competitive superiority" (Newmark, 2004).

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[10] U.S. Census Bureau (2022). *North American Industry Classification System*. Retrieved from https://www.census.gov/naics/

[11] Data available at https://www2.census.gov/programs-surveys/susb/tables/2017/us_6digitnaics_rcptsize_2017.xlsx. Accessed 11/7/2022. We note the publication of data from the 2022 Economic Census will not occur until late 2023 or early 2024.

The table provides additional evidence to examine these issues. In addition to the percent values claimed by the largest companies in the product categories, it includes the Herfindahl-Hirschman Index (HHI) for industries based on value added. This index provides a signal of how concentrated market power is across a particular industry.

The U.S. Department of Justice (DOJ) and the Federal Trade Commission (FTC) use the HHI to identify markets where there are potential anti-trust concerns. They consider markets with an HHI below 1,000 to be unconcentrated; markets with HHI between 1,000 and 1,800 are considered moderately concentrated, and markets with HHI above 1,800 to be "highly concentrated" (U.S. EPA, 2013). For a given market, the HHI is calculated by squaring the market share of each firm competing in the market, then summing the squared shares, as shown in the following equation:

$HHI = \sum_i s_i^2$, where s_i is the market share of the i^{th} firm.

Table 2-4: Concentration Findings of Affected Group I Industries

NAICS	Name of Industry	HHI Value*	Finding
325110	Petrochemical Manufacturing	2,868.4	Concentrated
325211	Plastics Material and Resin Manufacturing	409.9	Unconcentrated
325212	Synthetic Rubber Manufacturing	652.6	Unconcentrated
325998	All Other Miscellaneous Chemical Product and Preparation Manufacturing	164.8	Unconcentrated

Notes: *HHI is based on the 50 largest companies for each NAICS code. HHI for years after 2012 are not available since comprehensive concentration data from the 2017 Economic Census is not yet available. This value is found using "value added" which is a measure of manufacturing activity. Value added is derived by subtracting the cost of purchased inputs from the value of shipments.

Source: US Census. Economic Census (August 2015). https://www.census.gov/data/tables/2012/econ/census/manufacturing-reports.html

By the DOJ definition above, the only product category for which markets could be considered concentrated by the HHI was petrochemical manufacturing in 2012. Market concentration can develop due to various barriers to entry, pushing out potential entrants into a market. Barriers such as supply chain connection, capital requirements, and access to human capital can push certain industries to concentrate. Factors like these may be relevant in the case of the concentration of petrochemical manufacturing. However, there is evidence of a competitive market for the other synthetic rubber industries impacted by this regulation.

Competition for the synthetic rubber industries can arise due to a number of factors. The products of these industries can in some cases be substituted for one another. Other natural rubbers and imported products can also act as substitutes for these products. The presence of these alternatives can create excess capacity and can lead to falling prices for these industries.

2.2.3 Prices for Group I Industries

From 2012 to 2021, product prices for the wider chemical manufacturing sector (NAICS 325) have increased overall, but the trend has been marked with some volatility over the years. Prices began falling in 2015, stayed steady and then increased considerably in 2017 and 2018, and increased sharply in 2021 by almost 12 percent year-over-year. Table 2-5 shows this erratic pattern in detail.

Table 2-5: Chemical Manufacturing (NAICS 325) Product Price Index, 2012-2021 (2012 = 100)

NAICS 325	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2012-2021
Chemical Manufacturing	100.0	101.4	103.4	101.7	102.6	106.6	111.5	112.2	111.0	124.0	
Change from Previous Year		1.4	2.0	-1.7	0.9	4.0	4.8	0.7	-1.2	13.0	24.0
% Change from Previous Year		1.4%	2.0%	-1.6%	0.9%	3.9%	4.5%	0.7%	-1.1%	11.7%	24.0%

Source: U.S. Department of Labor, Bureau of Labor Statistics. Industries at a Glance: Chemical Manufacturing - NAICS 325. https://www.bls.gov/iag/tgs/iag325.htm

Table 2-6 shows a closer look at prices for synthetic rubber and related products from 2012 to 2021. Note that changes in product prices do not directly relate to the changes in synthetic rubber prices. Over this period, synthetic rubber prices fell considerably with a clear surge around 2017. This increase was a result of various supply-side conditions including growing costs in inputs to Styrene Butadiene Rubber (SBR), technical issues related to several manufacturing locations equipment failures affecting around 40 percent of U.S. styrene production, shortage of butadiene as well as its feedstock materials due to production issues, and other production issues. Tires and pneumatic tire prices remained relatively steady with only modest year to year changes, whereas rubber and plastics hose prices increased overall with some volatility in years 2013, 2015, and 2021.

Additionally, while not shown in the RIA, prices for natural rubber did not directly match the price changes in natural rubber as might be assumed from their substitutability. This is due to natural rubber following the supply-side constraint of agricultural inputs, whereas synthetic rubbers face the constraint of the availability and price of hydrocarbons. Moreover, the demand for rubbers is application dependent and may be based on the physical properties such as heat resistance and tear strength necessary for a particular use. This means substitutability of synthetic rubbers cannot be widely determined without knowing the needs of certain rubber applications (Wagner, 2020).

Table 2-6: Producer Price Index of Synthetic Rubber, 2012-2021 (Index for 2012 is normalized to 100)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2012-2021
Synthetic Rubber	100.0	88.3	85.7	75.3	73.8	80.2	82.3	78.9	73.3	85.8	
YoY Change		-11.7	-2.6	-10.4	-1.5	6.4	2.1	-3.4	-5.6	12.5	-14.2
% YoY Change		-11.7%	-2.9%	-12.1%	-2.0%	8.7%	2.6%	-4.1%	-7.1%	17.1%	-14.2%
Tires, Tubes, Tread, and Repair Materials	100.0	98.2	95.8	93.8	92.4	93.4	94.6	95.6	95.9	100.1	
YoY Change		-1.8	-2.4	-2.0	-1.4	1.0	1.2	1.0	0.3	4.2	0.1
% YoY Change		-1.8%	-2.4%	-2.1%	-1.5%	1.0%	1.3%	1.1%	0.3%	4.4%	0.1%
Pneumatic Tires (on-road, off-road, and other)	100.0	98.2	95.7	93.6	92.1	93.1	94.3	95.3	95.6	99.7	
YoY Change		-1.8	-2.5	-2.1	-1.5	1.0	1.2	1.1	0.3	4.1	-0.3
% YoY Change		-1.8%	-2.5%	-2.2%	-1.6%	1.1%	1.3%	1.1%	0.3%	4.3%	-0.3%
Rubber and Plastics Hose	100	104.1	105.2	104.0	105.3	106.0	109.2	112.7	114.0	122.1	
YoY Change		4.1	1.1	-1.2	1.3	0.7	3.2	3.5	1.3	8.1	22.1
% YoY Change		4.1%	1.0%	-1.1%	1.2%	0.6%	3.1%	3.2%	1.1%	7.1%	22.1%
Rubber and Plastics Hose (for on- and off-road vehicles)	100	106.7	106.5	102.1	105.2	105.3	109.3	111.8	112.7	114.6	
YoY Change		6.7	-0.18	-4.4	3.0	0.1	4.0	2.5	0.8	1.9	14.6
% YoY Change		6.7%	-0.2%	-4.1%	3.0%	0.1%	3.8%	2.3%	0.7%	1.7%	14.6%

Note: “YoY” is an acronym for “Year over Year.”

Source: Federal Reserve Economic Data, Economic Research Division, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/WPU071102, https://fred.stlouisfed.org/series/WPU0712, https://fred.stlouisfed.org/series/WPU0712010, https://fred.stlouisfed.org/series/WPU07130411, https://fred.stlouisfed.org/series/WPU071304118

2.2.4 General Production Description of Group I Industries

Synthetic rubber production requires the synthesis of monomers (derived from petrochemicals), followed by their polymerization. This process results in an aqueous suspension of rubber particles, or the latex, which may then be processed into marketable, dry, raw rubber. Synthetic rubbers are usually compounded with various additives and then molded, extruded, or calendared into the desired solid form. A percentage of elastomer production is also supplied in the form of water dispersions, called latexes (primarily used in foam rubber). HAP emission sources in synthetic rubber facilities include equipment leaks, process vents, wastewater, and storage tanks. It is important to note that elastomer production sites subject to this standard may be collocated with other production facilities that are, or will be, subject to NESHAP standards other than the Group I NESHAP. For example, a refining facility, chlorine plant, SOCMI facility, or non-elastomer polymer facility could be located on the same site as Group I production units.

2.2.5 Product Description of Group I Industries

The affected Group I elastomers are classified as synthetic rubbers which have specific elasticity and yield properties. Synthetic rubbers are either used as stand-alone products, or are compounded with natural rubber, other thermoplastic materials, or additives, depending on the desired end-use characteristics. This section describes the properties of each elastomer individually and identifies its primary end uses. Portions of this section are adapted from the *Economic Impact Analysis for the Polymers and Resin Group I NESHAP* (EPA, 1995).

2.3.1.1 Butyl Rubber (Including Halobutyl Rubber)

Butyl rubbers are copolymers of isobutylene (also known as isobutene) and other monomers. Other typical monomers include isoprene and methylstyrene. Most butyl rubber is produced by precipitation polymerization, although other methods may be used. Halobutyl rubber is a type of butyl rubber elastomer produced using halogenated copolymers and is typically used as a sealant. Characteristics of butyl rubber include low permeability to gases and high resistance to tear and aging. Butyl rubber is used as an input to the production of tires, tubes, and tire products. It is also used into the production of inner tubes because of its low air permeability. Butyl rubber is used in the production of automotive and mechanical goods, adhesives and caulks like halobutyl rubber (Thomas, 2022a).

Butyl rubber had a total trade of $592 million in 2020. Between 2019 and 2020, the exports of butyl rubber decreased by 0.71 percent, from $596 million to $592 million. Russia had the highest total exports of butyl rubber, valued at $193 million, while the US was third at $65.5 million. For the same year, China was the largest importer at $197 million (OEC, 2022d).

Halobutyl rubber had a total trade of $1.59 billion in 2020. Between 2019 and 2020, the exports of halobutyl rubber decreased by 19.3 percent, from $1.97 billion to $1.59 billion. Singapore had the highest total exports of halobutyl rubber, valued at $266 million, while the US was fourth at $239 million. For the same year, China was the largest importer at $291 million, whereas the U.S. was fifth highest at $108 million (OEC, 2022e).

2.3.1.2 Epichlorohydrin Elastomers (EPI)

The production of EPI uses epichlorohydrin, ethylene oxide, and allyl glycetal ether, which are combined in a polymerization process. Due to its low gas permeability and resistance to heat, fuel, and abrasion, EPI is primarily used in automotive applications including gaskets, hoses, and seals.[12] Market information on epichlorohydrin elastomers markets was limited.

2.3.1.3 Ethylene-Propylene Rubber (EPDM)

The ethylene-propylene category includes both ethylene-propylene copolymers (EPD) and ethylene-propylene terpolymers (EPDM). EPDM is produced from the polymerization of ethylene and propylene, which may occur in either a solution process or a suspension process. EPDM is characterized by lower cost relative to other elastomers, and resistance to cracking, low temperature flexibility, and weather. EPDM compounds have been developed for many different applications including automotive, industrial, construction, and HVAC. End uses include roofing membranes, impact modifiers, oil additives, automobile parts, gaskets and seals, and hoses and belts. The wide range of uses of this elastomer is attributable to its multifunctional nature (Thomas, 2022b).

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[12] BRP Manufacturing (2000). *Epichlorohydrin Rubber*. https://brpmfg.com/epichlorihydrin-rubber/epichlorohydrin-rubber/

EPDM had a total trade value of $1.57 billion in 2020. Between 2019 and 2020, the exports of EPDM rubber decreased by 18.2 percent, from $1.92 billion to $1.57 billion. The U.S. had the highest total exports of EPDM rubber, valued at $444 million. For the same year, China was the largest importer at $282 million, whereas the U.S. was fourth highest, at $90.8 million (OEC, 2022f).

2.3.1.4 Chlorosulfonated Polyethylene (Hypalon^{TM})

Chlorosulfonated polyethylene, also known by the discontinued trade name "Hypalon^{TM}" (Anixter, 2022), is formed from polyethylene through a chlorination and chlorosulfonation process. Chlorosulfonated polyethylene is characterized by excellent resistance to ozone, oxidation, UV rays, and weather. Uses of chlorosulfonated polyethylene include coatings for roofs and tarpaulins, hose construction, wire coverings, industrial rolls, and sporting goods (Industrial Rubber Goods, 2022). Market information on Chlorosulfonated polyethylene markets was limited.

2.3.1.5 Nitrile Butadiene Latex (NBL)

Nitrile butadiene latex (NBL) is a polymer consisting primarily of unsaturated nitriles and dienes, usually acrylonitrile and 1,3-butadiene, and is polymerized by free radical emulsion through advanced techniques, that is sold as a latex. It is used in several applications because of its low cost, ease of processing, and low flammability. NBL is also used in several applications like gloves and storage because of its oil resistance (Senlos Chem, 2022).

NBL had a total trade value of $1.6 billion in 2020. Between 2019 and 2020, the exports of NBL rubber increased by 33.8 percent, from $1.19 billion to $1.6 billion. South Korea had the highest total exports of NBL, valued at $886 million. For the same year, Malaysia was the largest importer at $1.08 billion. The U.S. was not among the five largest exporters or importers of NBL (OEC, 2022g).

2.3.1.6 Nitrile Butadiene Rubber (NBR)

Nitrile butadiene rubber (NBR) is a copolymer of acrylonitrile and butadiene. Its most significant characteristic is its resistance to mineral oils, vegetable oils, and hydraulic fluids. NBR is the preferred product for gasoline hoses, gaskets, and printing rolls. Many of the properties of nitrile rubber are directly related to the proportion of acrylonitrile in the rubber. NBR is used in many hose applications where oil, fuel, chemicals, and solutions are transported. In powder form, NBR is used in cements, adhesives, and brake linings, and in plastics modification. NBR is also used in belting and cable, in addition to its uses in O-rings and seals, adhesives and sealants, sponges, and footwear (Polymerdatabase, 2022a).

NBR had a total trade value of $890 million in 2020. Between 2019 and 2020, the exports of NBR decreased by 16.8 percent, from $1.07 billion to $890 million. South Korea had the highest total exports of NBR, valued at $197 million, while the U.S. was fourth at $101 million. For the same year, China was the largest importer at $187 million, whereas the U.S. was third highest at $81.3 million (OEC, 2022h).

2.3.1.7 Neoprene

Polychloroprene, also known as Neoprene, is produced from chloroprene through an emulsion process. It is characterized by its high flexibility, resistance to oils, strength, and resistance to abrasion, making it suitable for many diverse uses. Neoprene is similar to NBR in end uses, given that the primary use is for hoses and belts, with the remaining uses allocated among mechanical, adhesive, and wire and cable end uses. In latex form, Neoprene is used to manufacture household and industrial gloves (Polymerdatabase , 2022b).

In 2021, the total neoprene market was valued at $2.23 billion, with the Asia-Pacific market holding 40 percent of the market share. Acumen Research and Consulting projects a compound annual growth rate of 2.6 percent from 2022 to 2030. Two identified key market drivers are an increased adoption of neoprene rubber in the automotive sector and continual growth in construction and electronics industries in emerging economies. Denka is also a prominent manufacturer in this market, producing over 23 percent of neoprene (Acumen Research and Consulting, 2022).

2.3.1.8 Styrene-Butadiene Latex (SBL)

Styrene-butadiene latex (SBL) is a polymer consisting primarily of styrene and butadiene monomer units produced using an emulsion process and sold as a latex. Most commercial styrene-butadiene polymers are heavily crosslinked, so they have a high gel content. This provides a greater degree of toughness, strength, and elasticity compared to other materials, allowing for its usefulness as a latex. SBL is commonly used as a “coating in paper products, such as magazines, flyers and catalogs, to achieve high gloss, good printability, and resistance to oil and water.” It’s also a popular choice as an adhesive in construction applications (Mallard Creek Polymers, 2020).

SBL had a total trade value of $939 million in 2020. Between 2019 and 2020, the exports of SBL decreased by 13.4 percent, from $1.8 billion to $939 million. Germany had the highest total exports of SBL, valued at $255 million, while the U.S. was second at $122 million. For the same year, China was the largest importer at $165 million (OEC, 2022i).

2.3.1.9 Styrene-Butadiene Rubber (SBR)

Styrene-butadiene rubber (SBR) is produced in the largest volume of all the synthetic rubbers. Its chemical properties include favorable performance in extreme temperatures, resistance to cracking and abrasion, and stability over time. The dominance of SBR among synthetic rubber types is attributable to its availability and processability. The availability of styrene and butadiene in fossil hydrocarbons make these two inputs an abundant source of synthetic rubber, and styrene and butadiene can be combined into rubber compounds which are easily processed into tire molds. Types of SBR differ in the ratios of styrene to butadiene, their content of additives, or the type of polymerization process used during the manufacturing process. The substitutability of SBR with natural rubber is primarily determined by the fluctuating prices of each, and by the properties required in the end product (Polymerdatabase , 2022c).

SBR had a total trade value of $4.49 billion in 2020. Between 2019 and 2020, the exports of SBR rubber decreased by 19.8 percent, from $5.6 billion to $4.49 billion. South Korea had the highest total exports of SBR, valued at $713 million. For the same year, China was the largest importer at $627 million, whereas the U.S. was second highest at $472 million (OEC, 2022j).

2.3.1.10 Polybutadiene Rubber (PBR)

Polybutadiene rubber (PBR) is formed from butadiene which undergoes emulsion polymerization. After SBR, polybutadiene rubber is the synthetic rubber produced in the second highest volume. It is also a relatively low-cost elastomer. The major use of PBR is in tires for the side walls and treads. To augment properties such as traction, rolling and abrasion resistance, it is typically compounded with other elastomers such as natural rubber and SBR. Other applications are golf ball cores, inner tubes of hoses for sandblasting, and covers for pneumatic and water hoses. Polybutadiene is also used as a toughening agent in the production of certain plastics (Polymerdatabase, 2022d).

PBR had a total trade of $2.35 billion in 2020. Between 2019 and 2020, the exports of PBR decreased by 25.1 percent, from $3.14 billion to $2.35 billion. South Korea had the highest total exports of PBR, valued at $427 million, while the U.S. was third highest, at $241 million. For the same year, China was the largest importer at $320 million (OEC, 2022k).

2.2.6 *Group II Industry Profile*

This section reviews Group II industries, which are characterized by the following source categories: epoxy and resins production and non-nylon polyamides production. The affected firms are more explicitly identified by size and economic impacts in a later section. Like the Group I facilities, each facility is identified using a NAICS code. Among the identified facilities in Group II, there are three unique NAICS codes represented in the associated NESHAP and the U.S. economy. Table 2-7 provides 2017 data for these industries in the US economy, not only considering facilities directly impacted by this rulemaking.[11]

Table 2-7: Polymers and Resin Group II Industries

NAICS	Name of Industry	Number of Facilities (% of Total Facilities)	Total Revenue in 2017 (in Billions)	Total Employment in 2017
324110	Petroleum Refineries	1 (20%)	$478.60	63,594
325110	Petrochemical Manufacturing	1 (20%)	$52.67	9,369
325211	Plastics Material and Resin Manufacturing	3 (60%)	$89.52	75,998

2.2.7 *Industry Organization of Group II Industries*

This section provides information on the structure of the covered epoxy and resins industries, and the characteristics of the market organization of the affected Group II industries. This is an attempt to characterize the impacts this proposed regulation can have in more detailed terms.

Table 2-8 discusses how the firms in each product category can be characterized by market concentration: the market share percentage for the 50 largest firms of the affected industries by NAICS code.

Table 2-8: Concentration Findings of Affected Group II Industries

NAICS	Name of Industry	HHI Value*	Finding
324110	Petroleum Refineries	786	Unconcentrated
325110	Petrochemical Manufacturing	2,868.4	Concentrated
325211	Plastics Material and Resin Manufacturing	409.9	Unconcentrated

Notes: *HHI is based on the 50 largest companies for each NAICS code. HHI for years after 2012 are not available since comprehensive concentration data from the 2017 Economic Census is not yet available. This value is found using “value added”

which is a measure of manufacturing activity. Value added is derived by subtracting the cost of purchased inputs from the value of shipments.
Source: US Census. Economic Census (August 2015). https://www.census.gov/data/tables/2012/econ/census/manufacturing-reports.html

As presented in Section 2.2.1 and based on the given U.S. Department of Justice definition, only the petrochemical manufacturing markets could be considered concentrated in 2012. Whereas the HHI for both petroleum refineries and plastics materials and resin manufacturing markets suggest more competitive, unconcentrated industry markets. Like synthetic rubbers, most affected facilities under this rule inhabit more competitive markets, which generally suppress the profit margins for certain firms and increases the price elasticity of demand. A market with higher price elasticity of demand shows a larger change in quantity demanded relative to a particular change in price.

2.2.8 Prices for Group II Industries

Like Group I industries, Group II industries are also a part of the chemical manufacturing sector (NAICS 325). More information on price for this sector can be found in Section 2.2.2. In this section, Table 2-9 shows a closer look at prices for epoxy and resins, and related products, from 2012 to 2021. Note that changes in the product prices of adhesives, coatings, and paper do directionally relate to price changes in the broader “Plastics Material and Resins Manufacturing” (Plastics and Resins) category, but the magnitude of these changes are varied.

Over this period, each product category saw overall prices increase with certain years with volatility in 2015 and 2019. In 2021, each product category saw its highest single-year spike in prices with Plastics and Resins increasing by over a third of its 2020 value. This one-year increase was largely a result of demand-side and supply-side conditions exacerbated by the Covid-19 pandemic. On the demand-side, Covid-19-related lockdowns increased the demand for delivered goods and therefore greater plastic packaging, while the healthcare industry augmented plastic demands for personal protective equipment (PPE). Supply-side issues also constrained the availability of plastics and resins due to related labor shortages or production slowdowns, as well as more widespread international supply chain difficulties (Pederson, 2021).

Table 2-9: Producer Price Index of Epoxy and Resins, 2012-2021 (2012 = 100)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2012-2021
Plastics Material and Resins Manufacturing	100.0	103.5	107.8	97.3	92.7	97.6	102.3	98.0	94.6	126.1	
YoY Change		3.5	4.3	-10.5	-4.6	4.9	4.7	-4.3	-3.5	31.6	26.1
% YoY Change		3.5%	4.2%	-9.7%	-4.7%	5.3%	4.8%	-4.2%	-3.6%	33.4%	26.1%
Adhesive Manufacturing: Synthetic Resin and Rubber Adhesives	100.0	100.7	102.1	101.3	100.2	101.7	104.2	106.5	107.0	113.0	
YoY Change		0.7	1.4	-0.8	-1.1	1.5	2.4	2.4	0.4	6.0	13.0
% YoY Change		0.7%	1.4%	-0.8%	-1.1%	1.5%	2.4%	2.3%	0.4%	5.6%	13.0%
Paint and Coating Manufacturing	100.0	101.3	102.1	101.0	100.5	101.6	105.3	110.0	112.1	121.3	
YoY Change		1.3	0.8	-1.1	-0.6	1.1	3.7	4.7	2.1	9.1	21.3
% YoY Change		1.3%	0.8%	-1.1%	-0.5%	1.1%	3.7%	4.4%	1.9%	8.2%	21.3%
Paper Manufacturing	100.0	102.2	103.6	103.4	102.6	105.2	108.9	110.2	108.6	117.6	
YoY Change		2.2	1.4	-0.2	-0.8	2.6	3.7	1.3	-1.6	9.0	17.6
% YoY Change		2.2%	1.4%	-0.2%	-0.8%	2.5%	3.5%	1.2%	-1.5%	8.3%	17.6%

Note: “YoY” is an acronym for “Year over Year”.
Source: Federal Reserve Economic Data, Economic Research Division, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/PCU325211325211, https://fred.stlouisfed.org/series/PCU3255203255204, https://fred.stlouisfed.org/series/PCU325510325510, https://fred.stlouisfed.org/series/PCU322322

2.2.9 Product Description and Markets of Group II Industries

The epoxy resins production source category involves the manufacture of basic liquid epoxy resins used in the production of glues, adhesives, plastic parts, and surface coatings. This source category does not include specialty or modified epoxy resins. The non-nylon polyamides production source category involves the manufacture of epichlorohydrin crosslinked non-nylon polyamides used primarily by the paper industry as an additive to paper products. Natural polymers, such as those contained in paper products, have little cross-linking, which allows their fibers to change position or separate completely when in contact with water. The addition of epichlorohydrin cross-linked non-nylon polyamides to these polymers causes the formation of a stable polymeric web among the natural fibers. Because the polymeric web holds the fibers in place even in the presence of water, epichlorohydrin cross-linked non-nylon polyamides are also referred to as wet-strength resins. HAP emission sources in Group II facilities include: equipment leaks, process vents, wastewater, and storage tanks.

The epoxy resin market had a size of $12.8 billion in 2022. Grand View Research projects a compound annual growth rate of 7.3 percent from 2022 to 2030, forecasting a 2030 revenue of $22.4 billion. A key market driver is an increased demand for paints and coatings due to increased construction spending in North America and Western Europe. In 2021, “paints and coating” accounted for more than 37 percent of revenue share of epoxy resin applications and Asia-Pacific accounted for more than 61 percent of revenue share by region of the market (Grand View Research, 2022).

The non-nylon polyamide resin market had a size of $3.27 billion in 2020. Between 2019 and 2020, the exports decreased by 10.5 percent, from $3.65 billion to $3.27 billion. Germany had the highest total exports, valued at $197 million, while the US was second at $529 million. For the same year, China was the largest importer at $502 million, whereas the US was fourth highest at $155 million (OEC, 2022l).

3 EMISSIONS AND ENGINEERING COST ANALYSIS

3.1 Introduction

3.1.1 HON

In general, the HON applies to chemical manufacturing process units (CMPUs) that: (1) produce one of the listed SOCMI chemicals, and (2) either use as a reactant or produce a listed organic HAP in the process. A CMPU refers to the collection of equipment assembled and connected by pipes or ducts to process raw materials and to manufacture an intended product. A CMPU consists of more than one unit operation. A CMPU includes air oxidation reactors and their associated product separators and recovery devices; reactors and their associated product separators and recovery devices; distillation units and their associated distillate receivers and recovery devices; associated unit operations; associated recovery devices; and any feed, intermediate and product storage vessels, product transfer racks, and connected ducts and piping. A CMPU includes pumps, compressors, agitators, pressure relief devices, sampling connection systems, open-ended valves or lines, valves, connectors, instrumentation systems, and control devices or systems. A CMPU is identified by its primary product.

The emissions sources affected by the current HON includes heat exchange systems and maintenance wastewater regulated under NESHAP subpart F; process vents, storage vessels, transfer racks, and wastewater streams regulated under NESHAP subpart G; equipment leaks associated with SOCMI processes regulated under NESHAP subpart H; and equipment leaks from certain non-SOCMI processes at chemical plants regulated under NESHAP subpart I.

As of July 1, 2022, there were 207 facilities that are major sources of HAP emissions in operation that are subject to the HON. The list of facilities located in the United States that are major sources of HAP and part of the SOCMI source category with processes subject to HON is available in the memorandum titled: “Lists of Facilities Subject to the HON, Group I and Group II Polymers and Resins NESHAPs, and NSPS subparts VV, VVb, III, NNN, and RRR” (ERG, 2023a).

3.1.2 P&R I (Subpart U)

The P&R I NESHAP generally follows and refers to the requirements of the HON, with an addition of requirements for batch process vents. Generally, the P&R I NESHAP applies to elastomer product process units (EPPUs) and associated equipment. Similar to a CMPU in the HON, an EPPU means a collection of equipment assembled and connected by hard-piping or duct work used to process raw materials and manufacture elastomer product. The EPPU includes unit operations, recovery operations, process vents, storage vessels, and equipment that are covered by equipment leak standards and produce one of the elastomer types listed as an elastomer product (*i.e.*, the list found in Section 1.0 above). An EPPU consists of more than one unit operation. An EPPU includes, as equipment, pumps, compressors, agitators, pressure relief devices, sampling connection systems, open-ended valves or lines, valves, connectors, surge control vessels, bottoms receivers, and instrumentation systems, and control devices or systems.

The emissions sources affected by the current P&R I NESHAP includes heat exchange systems and maintenance wastewater regulated under NESHAP subpart F; storage vessels, transfer racks, and wastewater streams regulated under NESHAP subpart G; equipment leaks regulated under NESHAP subpart H. Process vents are also regulated emission sources but, unlike the HON, these emissions sources are subdivided into front and back-end process vent process vents in P&R I. The front-end are unit operations prior to and including the stripping operations. These are further subdivided into continuous front-end process vents regulated under NESHAP subpart G and batch front-end process vents that are regulated according to the requirements within the P&R I NESHAP. Back-end unit operations include filtering, coagulation, blending, concentration, drying, separating, and other finishing operations, as well as latex and crumb storage. The requirements for back-end process vents are not subcategorized into batch or continuous and are also found within the P&R I NESHAP.

As of July 1, 2022, there were 19 facilities that are major sources of HAP emissions in operation that are subject to the P&R I NESHAP. The list of facilities located in the United States that are major sources of HAP is available in the memorandum titled: “Lists of Facilities Subject to the HON, Group I and Group II Polymers and Resins NESHAPs, and NSPS subparts VV, VVa, III, NNN, and RRR” (ERG, 2023a).

3.1.3 P&R II (Subpart W)

The P&R II NESHAP takes a different regulatory and format approach from the P&R I NESHAP but still refers to HON provisions for a portion of the standards. There are two basic subcategories of manufacturing sources in the P&R II NESHAP – basic liquid epoxy resins (BLR) and wet strength resins (WSR). A BLR means resins made by reacting epichlorohydrin and bisphenol A to from diglycidyl ether of bisphenol-A (DGEBPA). A WSR means polyamide/epichlorohydrin condensates which are used to increase the tensile strength of paper products.

The emission sources affected by the P&R II NESHAP are all HAP emission points within a facility related to the production of BLR or WSR. These emission points include process vents, storage tanks, wastewater systems, and equipment leaks. Equipment includes connectors, pumps, compressors, agitators, pressure relief devices, sampling connection systems, open-ended valves and lines, and instrumentation system in organic HAP service. Equipment leaks are regulated under the HON (*i.e.*, NESHAP subpart G).

Process vents, storage tanks, wastewater systems combined are regulated according to a production-based emission rate (*e.g.*, pounds HAP per million pounds BLR or WSR produced) standard for existing sources in both BLR (130 pounds) and WSR (10 pounds). For new sources, BLR requires 98 percent reduction or an overall limit of 5,000 pounds of HAP per year. New WSR sources are limited to 7 pounds of HAP per million pounds WSR produced.

As of July 1, 2022, there were 5 facilities that are major sources of HAP emissions in operation that are subject to the P&R II NESHAP. The list of facilities located in the United States that are major sources of HAP is available in the memorandum titled: “Lists of Facilities Subject to the HON, Group I and Group II Polymers and Resins NESHAPs, and NSPS subparts VV, VVa, III, NNN, and RRR” (ERG, 2023a).

3.2 Emission Points and Controls

The EPA evaluated developments in practices, processes, and control technologies for heat exchange systems, storage vessels, process vents, transfer racks, wastewater, and equipment leaks for processes subject to the HON, P&R I, and P&R II. Moreover, for the NSPS subpart VVa, we evaluated BSER for equipment leaks; and for the NSPS subparts III, NNN, and RRR we evaluated BSER for process vents associated with air oxidation units, distillation operations, and reactor processes, respectively. We analyzed costs and impacts for each emission source (*e.g.*, process vents) by each rule. For the different NSPS, we determined cost-effectiveness, cost per ton of emissions reduced, on a VOC basis. For each NESHAP, we determined cost-effectiveness on a HAP basis from the VOC emissions.

3.2.1 Heat Exchange Systems

Heat exchangers are devices or collections of devices used to transfer heat from process fluids to another process fluid (typically water) without intentional direct contact of the process fluid with the cooling fluid (*i.e.,* non-contact heat exchanger). There are two types of heat exchange systems: Closed-loop recirculation systems and once-through systems. Closed-loop recirculation systems use a cooling tower to cool the heated water leaving the heat exchanger and then return the newly cooled water to the heat exchanger for reuse. Once-through systems typically use surface freshwater (*e.g.*, from rivers) as the influent cooling fluid to the heat exchangers, and the heated water leaving the heat exchangers is then discharged from the facility.

Based on our review, we identified the following control option (a development in practice) for heat exchange systems: quarterly monitoring with the Modified El Paso Method, using a leak action level defined as a total strippable hydrocarbon concentration (as methane) in the stripping gas of 6.2 ppmv (and not allowing delay of repair of leaks for more than 30 days where a total strippable hydrocarbon concentration (as methane) in the stripping gas of 62 ppmv or higher is found). This option would also require re-monitoring at the monitoring location where the leak was identified to ensure that any leaks found are fixed. More information on these systems and control options can be found in the preamble for this rulemaking.

Table 3-1: VOC and HAP Cost Effectiveness for the Control Option Evaluated for Heat Exchange Systems at HON Facilities (2021$)

VOC Emission Reductions (tpy)	HAP Emission Reductions (tpy)	VOC Cost Effectiveness w/o Credits ($/ton)	HAP Cost Effectiveness w/o Credits ($/ton)	VOC Cost Effectiveness with Credits ($/ton)	HAP Cost Effectiveness with Credits ($/ton)
934	93	244	2,441	(656)	(6,559)

*A parenthesis around a number denotes a negative value.

3.2.2 Storage Vessels

Storage vessels are used to store liquid and gaseous feedstocks for use in a process, as well as to store liquid and gaseous products from a process. Most storage vessels are designed for operation at atmospheric or near atmospheric pressures; high pressure vessels are used to store compressed gases and liquefied gases. Atmospheric storage vessels are typically cylindrical with a vertical orientation, and they are constructed with either a fixed roof or a floating roof. Some, generally small, atmospheric storage vessels are oriented horizontally. High pressure vessels are either spherical or horizontal cylinders.

Below in Tables 3-2 through 3-4 is a presentation of different control options considered for storage vessels, and then costs and emissions reductions for the different regulatory options. More information on these systems and control options can be found in the preamble for this rulemaking.

Table 3-2: Summary of Storage Vessel Control Options Evaluated for the HON

Storage Vessel Control Option	Control Option Description
SV1	Revise the HON and P&R I NESHAP applicability threshold to require existing storage vessels between 38 m^3 (10,000 gal) and 151 m^3 (40,000 gal) with a vapor pressure $\geq$6.9 kPa to add control Control is assumed to be a retrofitted IFR
SV2	SV1 plus require upgraded deck fittings and controls for guide poles for all IFR storage vessels
SV3	Convert each EFR to an IFR through installation of a geodesic dome plus require upgraded deck fittings and controls for guide poles.

Table 3-3: Nationwide Emissions Reductions and Cost Impacts of Control Options Considered for Storage Vessels at HON Facilities

Control option	Total capital investment ($)	Total annualized costs ($/yr)	VOC emission reductions (tpy)	HAP emission reductions (tpy)	HAP cost effectiveness ($/ton)	HAP incremental cost effectiveness (from Option 1) ($/ton)
1	1,727,000	$327,400	58.0	40.6	8,070	-
2	2,191,500	$415,500	68.2	47.7	8,710	12,400
3	28,916,200	$4,065,700	84.3	59.0	68,880	N/A

Table 3-4: Nationwide Emissions Reductions and Cost Impacts of Control Options Considered for Storage Vessels at P&R I Facilities (not collocated with HON facilities)

Control option	Total capital investment ($)	Total annualized costs ($/yr)	VOC emission reductions (tpy)	HAP emission reductions (tpy)	HAP cost effectiveness ($/ton)	HAP incremental cost effectiveness (from Option 1) ($/ton)
1	109,000	20,700	3.7	2.6	7,960	-
2	131,000	24,800	4.1	2.9	8,550	13,700
3	912,200	128,300	2.7	1.9	67,500	N/A

3.2.3 Process Vents

A process vent is a gas stream that is discharged during the operation of a particular unit operation (*e.g.,* separation processes, purification processes, mixing processes, reaction processes). The gas stream(s) may be routed to other unit operations for additional processing (*e.g.,* a gas stream from a reactor that is routed to a distillation column for separation of products), sent to one or more recovery devices, sent to a process vent header collection system (*e.g.,* blowdown system) and APCD (*e.g.,* flare, thermal oxidizer, carbon adsorber), and/or vented to the atmosphere. Process vents may be generated from continuous and/or batch operations,[13] as well as from other intermittent. types of operations (*e.g.,* maintenance operations). If process vents are required to be controlled prior to discharge to the atmosphere to meet an applicable emissions standard, then they are typically collected and routed to an APCD through a closed vent system.

Tables 3-5 through 3-10 include a summary of control options for process vents, and costs and emission reductions for each option and type of process vents considered under each of the rules in this proposed rulemaking. More information on these systems and control options can be found in the preamble for this rulemaking.

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[13] P&R I and P&R II regulate process vents from both continuous and batch operations. The HON and NSPS subparts III, NNN, and RRR only regulate process vents if some, or all, of the gas stream originates as a continuous flow.

Table 3-5: Summary of Continuous Process Vent Control Options Evaluated for the HON and P&R I NESHAP

Process Vent Control Option	Control Option Description
PV1	• Remove TRE concept in its entirety from HON and P&R I NESHAP. • Remove 50 ppmv and 0.005 scmm Group 1 process vent thresholds from HON and P&R I NESHAP. • Redefine a HON and P&R I NESHAP Group 1 process vent (require control) as any process vent that emits ≥1.0 lb/hr of total organic HAP.
PV2	• Same as PV1, but redefine a HON and P&R I NESHAP Group 1 process vent (require control) as any process vent that emits ≥0.10 lb/hr of total organic HAP.
PV3	• Keep TRE concept in HON and P&R I NESHAP, but change index value threshold from 1.0 to 5.0.$^{(1)}$ • Keep 50 ppmv and 0.005 scmm Group 1 process vent thresholds in HON and P&R I NESHAP.

Table 3-6: Nationwide Emissions Reductions and Cost Impacts of Control Options Considered for Continuous Process Vents at HON Facilities

Control option	Total capital investment ($)	Total annualized costs ($/yr)	VOC emission reductions (tpy)	HAP emission reductions (tpy)	HAP cost effectiveness ($/ton)
1	1,218,000	3,150,000	436	436	7,200
2	5,732,000	10,329,000	809	533	19,400
3	1,493,000	3,208,000	441	441	7,300

Table 3-7: Nationwide Emissions Reductions and Cost Impacts of Control Options Considered for Continuous Process Vents at P&R I Facilities

Control option	Total capital investment ($)	Total annualized costs ($/yr)	VOC emission reductions (tpy)	HAP emission reductions (tpy)	HAP cost effectiveness ($/ton)
1	198,000	586,000	51.0	51.0	11,500
2	557,000	1,242,000	80.1	72.4	17,200
3	215,000	590,000	54.8	54.8	10,800

Table 3-8: Nationwide Emissions Reductions and Cost Impacts of Control Options Considered for Batch Front-end Process Vents at P&R I Facilities

Control option	Total capital investment ($)	Total annualized costs ($/yr)	VOC emission reductions (tpy)	HAP emission reductions (tpy)	HAP cost effectiveness ($/ton)
1	811,000	650,700	105	105	6,200

Process Vents – Subpart IIIa, NNNa, and RRRa NSPS

Table 3-9: Average Cost and Emission Reductions for Process Vents Subject to the HON Used for the Suite of Proposed Process Vent Requirements Evaluated for the NSPS subparts IIIa, NNNa, and RRRa

Description	Total Capital Investment ($)	Total Annual Cost ($/yr)	Total Annual Cost w/ Recovery Credits ($/yr)	VOC Emission Reductions (tpy)
Flare monitoring requirements[1]	3,752,200	789,200	789,200	93
Maintenance vent requirements[2]	-	460	460	-
Revising the standard from a TRE calculation to control of all vent streams[3]	39,300	98,400	98,400	9.1
Adsorber monitoring (carbon cannisters)(4)	26,500	2,500	2,500	0.21

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[1] For additional details, see the document titled *Control Option Impacts for Flares Located in the SOCMI Source Category that Control Emissions from Processes Subject to HON and for Flares that Control Emissions from Processes Subject to Group I and Group II Polymers and Resins NESHAPs*, which is available in the docket for this rulemaking.

[2] For additional details, see the document titled *Review of Regulatory Alternatives for Certain Vent Streams in the SOCMI Source Category that are Associated with Processes Subject to HON and Processes Subject to Group I and Group II Polymers and Resins NESHAPs*, which is available in the docket for this rulemaking.

[3] For additional details, see the document titled *Clean Air Act Section 112(d)(6) Technology Review for Continuous Process Vents Located in the SOCMI Source Category that are Associated with Processes Subject to HON, Continuous Front-end and Batch Front-end Process Vents Associated with Processes Subject to Group I Polymers and Resins NESHAP, and Process Vents Associated with Processes Subject to Group II Polymers and Resins NESHAP*, which is available in the docket for this rulemaking.

[4] For additional details, see the document titled *Analysis of Monitoring Costs and Dual Bed Costs for Non-Regenerative Carbon Adsorbers Used in the SOCMI Source Category that are Associated with Processes Subject to HON and for Non-Regenerative Carbon Adsorbers that are Associated with Processes Subject to Group I Polymers and Resins NESHAP*, which is available in the docket for this rulemaking.

Table 3-10: Nationwide Emissions Reductions and Cost Impacts of Control Options Considered for Non-HON Vent Streams Triggering NSPS Subparts IIIa, NNNa, and/or RRRa

Scenario	Total Capital Investment ($)	Total Annual Cost ($/yr)	Total Annual Cost w/ Recovery Credits ($/yr)	VOC Emission Reductions (tpy)	Cost-effectiveness w/ Recovery Credits ($/ton VOC)
Scenario 1 (*i.e.,* one affected facility at a new greenfield facility)	1,665,300	461,000	461,000	93	4,960
Scenario 2 (*i.e.,* new affected facility at six existing facilities)	7,609,500	1,780,000	1,780,000	392	4,540
Scenarios 3 and 4 (*i.e.,* 12 existing affected facilities modified or triggers the reconstruction requirements)	15,192,500	3,558,000	3,558,000	783	4,540
Total	24,467,300	5,799,800	5,799,800	1,269	4,570

3.2.4 Transfer Racks

We did not identify any developments in practices, processes, or control technologies for HON transfer racks that would achieve a greater HAP emission reduction beyond the emission reduction already required by the HON. Therefore, under CAA section 112(d)(6) we are not proposing any changes to the HON for this emission process group based on our technology review.[14] We note, however, that under CAA section 112(d)(2) and (3) we are proposing changes to the applicability threshold for HON transfer racks to fill a regulatory gap in the current HON.

3.2.5 Wastewater

HAP are emitted into the air from wastewater collection, storage, and treatment systems that are uncovered or open to the atmosphere through volatilization of organic compounds at the liquid surface. Emissions occur by diffusive or convective means, or both. Diffusion occurs when organic concentrations at the water surface are much higher than ambient concentrations. The organics volatilize, or diffuse into the air, to reach equilibrium between aqueous and vapor phases. Convection occurs when air flows over the water surface, sweeping organic vapors from

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[14] P&R I and P&R II sources do not have transfer racks as emission sources.

the water surface into the air. The rate of volatilization is related directly to the speed of the air flow over the water surface.

The HON defines wastewater to mean water that: (1) Contains either: (i) an annual average concentration of Table 9 (to NESHAP subpart G) compounds of at least 5 ppmw and has an annual average flow rate of 0.02 liter per minute (lpm) or greater or (ii) an annual average concentration of Table 9 (to NESHAP subpart G) compounds of at least 10,000 ppmw at any flow rate, and that (2) is discarded from a CMPU that meets all of the criteria specified in 40 CFR 63.100 (b)(1) through (b)(3). Wastewater is process wastewater or maintenance wastewater.

P&R I defines wastewater similarly to how the term is defined in the HON, except instead of referring to Table 9 (to NESHAP subpart G) compounds, P&R I refers to Table 5 (to NESHAP subpart U) compounds. P&R II defines wastewater as aqueous liquid waste streams exiting equipment at an affected source. No further stratification into groups for applicability is specified.

Below in Tables 3-11 and 3-12 are costs and emission reductions for control options considered for wastewater under the proposed HON amendments, and P&R I. More information on these systems and control options can be found in the preamble for this rulemaking.

Table 3-11: Nationwide Emissions Reductions and Cost Impacts of Control Options Considered for Wastewater Streams at HON Facilities

Control option	Total capital investment ($)	Total annualized costs ($/yr)	VOC emission reductions (tpy)	HAP emission reductions (tpy)	HAP cost effectiveness ($/ton)
1	504,766,000	210,739,500	2,755	2,755	76,500

Table 3-12: Nationwide Emissions Reductions and Cost Impacts of Control Options Considered for Wastewater Streams at P&R I Facilities

Control option	Total capital investment ($)	Total annualized costs ($/yr)	VOC emission reductions (tpy)	HAP emission reductions (tpy)	HAP cost effectiveness ($/ton)
1	46,847,800	22,548,200	220	220	102,500

3.2.6 Equipment Leaks

Emissions of VOC and HAP from equipment leaks occur in the form of gases or liquids that escape to the atmosphere through many types of connection points (*e.g.,* threaded fittings) or through the moving parts of certain types of process equipment during normal operation.

Equipment regulated by the HON, P&R I, and P&R II includes agitators, compressors, connectors, instrumentation systems, OEL, PRDs, pumps, sampling collection systems, and valves[15] that contain or contact material that is 5 percent by weight or more of organic HAP, operate 300 hours per year or more, and are not in vacuum service.

Based on the costs and emission reductions for the options, we determined that none of them are cost effective. Therefore, we are not proposing to revise the HON, P&R I, and P&R II to reflect the requirements of these options pursuant to CAA section 112(d)(6). However, tighter requirements on equipment leaks will be proposed under Subpart VVb NSPS. Table 3-13 provides costs and emission reductions for these tighter requirements by type of affected facilities as well as the total costs and emission reductions. More information on these systems and control options can be found in the preamble for this rulemaking.

Table 3-13: Nationwide Emissions Reductions and Cost Impacts of Control Options Considered for Affected Facilities Triggering NSPS Subpart VVb

Scenario	**Total Capital Investment ($)**	**Total Annual Cost ($/yr)**	**Total Annual Cost w/ Recovery Credits ($/yr)**	**VOC Emission Reductions (tpy)**	**Cost-effectiveness w/ Recovery Credits ($/ton VOC)**
Scenario 1 (*i.e.,* two affected facilities at a new greenfield facility)	416,600	77,500	60,900	18	3,380
Scenario 2 (*i.e.,* 34 new affected facilities)	7,081,700	1,317,900	1,035,800	313	3,310
Scenarios 3 and (*i.e.,* one modified existing affected facility)	208,300	38,800	30,500	9	3,390
Total	**7,706,600**	**1,434,200**	**1,127,200**	**340**	**3,320**

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[15] We believe P&R II contains a typographical error in that valves are currently excluded from the definition of equipment leaks at 40 CFR 63.522; see section III.D.10 of this preamble for our rationale for this conclusion and our proposal to address this issue.

3.2.7 Flares

Flares that control emissions from processes subject to HON or the P&R I NESHAP are required to meet certain design and operating requirements as specified in 40 CFR 63.11. The available data at the time these NESHAP were promulgated suggested that flares meeting these design and operating requirements would achieve a minimum destruction efficiency of no less than 98 percent emissions control. Relatively recent evidence through Passive Fourier Transform Infrared spectroscopy (PFTIR) testing suggests that steam- and air-assisted flares can have a significant degradation in destruction efficiency when operated at high turndown or at other times when steam- and air-assist rates are too high (EPA, 2012). As many of the flares operated at HON and P&R I facilities are steam- or air-assisted, concerns of poor flare destruction efficiency are particularly significant. We note that a substantial portion of the costs, both capital and annual, for the proposed HON and P&R I amendments and for this entire proposed action, are from the proposed control requirements for flares. Tables 3-14 and 3-15 present cost and emission reductions for flare control options proposed as part of the HON and P&R I amendments under this proposed action. More information on these systems and control options can be found in the preamble for this rulemaking.

Table 3-14: Nationwide Cost Impacts (2021$) for Flares in the SOCMI Source Category that Control Emissions from HON Processes including P&R I Flares Collocated with HON Processes

Control Option	Total Capital Investment (MM$)	Total Annualized Cost (MM$/yr)
Flare Operational and Monitoring Requirements	323.1	67.8
Work Practice Standards for Flares Operating Above Their Smokeless Capacity	3.34	0.79
Nationwide Total	**326.4**	**68.6**

(a) We were unable to quantify emissions reductions for this option but anticipate some excess emissions reductions.

(b) VOC and HAP emission reductions are anticipated excess emissions impacts based on ensuring flares achieve the MACT level of control.

Table 3-15: Nationwide Cost Impacts (2021$) for Flares that Control Emissions from P&R I Processes

Control Option	Total Capital Investment (MM$)	Total Annualized Cost (MM$/yr)
Flare Operational and Monitoring Requirements	6.93	1.46
Work Practice Standards for Flares Operating Above Their Smokeless Capacity	0.08	0.02
Nationwide Total	**7.1**	**1.48**

Table 3-16: Nationwide Flare Control Efficiency and Emission Reduction Estimates for Flares in the SOCMI Source Category that Control Emissions from HON Processes

Control Alternative Description	Average Destruction Efficiency[(a)]	VOC Emissions (tons/yr)	HAP Emissions (tons/yr)	VOC Emission Reductions (tons/yr)	HAP Emission Reductions (tons/yr)
Baseline	85.9	21,455	5,237		
NHV_{CZ} ≥270 Btu/scf on 15- minute average with allowance to use 1,212 Btu/scf as net heating value for hydrogen	98.6	2,130	520	19,325	4,717

Table 3-17: Nationwide Flare Control Efficiency and Emission Reduction Estimates for Flares that Control Emissions from P&R I Processes

Control Alternative Description	Average Destruction Efficiency[(a)]	VOC Emissions (tons/yr)	HAP Emissions (tons/yr)	VOC Emission Reductions (tons/yr)	HAP Emission Reductions (tons/yr)
Baseline	85.9	626	156		
NHV_{CZ} ≥270 Btu/scf on 15- minute average with allowance to use 1,212 Btu/scf as net heating value for hydrogen	98.6	62	16	564	141

3.2.8 Fenceline Monitoring

Fenceline monitoring refers to the placement of monitors along the perimeter of a facility to measure pollutant concentrations. Coupled with requirements for root cause analysis and corrective action upon triggering an actionable level, this work practice standard is a development in practices considered under CAA section 112(d)(6) for the purposes of managing fugitive emissions. Below in Tables 3-18 and 3-19 are cost and emission reductions associated with several fenceline monitoring scenarios or options in the proposed HON and P&R I amendments. More information on fenceline monitoring and implementation options can be found in the preamble for this rulemaking.

Table 3-18: Nationwide Cost Impacts of Fenceline Monitoring for HON

Monitoring scenario	# Facilities Impacted	Monitoring option description	Total capital investment ($)	Total annualized costs (million $/yr)
1	35	Passives only (1 analyte)*	4,016,000	2,141,000
2	46	Passives only (2 analytes)	2,295,000	1,282,000
3	9	Cannisters only	115,500	5,366,000
4	16	Cannisters and passives (1 analyte)	1,606,000	10,397,000
5	20	Cannisters and passives (2 analytes)	1,721,000	12,869,000

*An analyte is the chemical substance being measured. For these fenceline monitoring options, the analyte is a HAP monitored under HON and P&R I requirements.

Table 3-19: Nationwide Cost Impacts of Fenceline Monitoring for P&R I

Monitoring scenario	# Facilities Impacted	Monitoring option description	Total capital investment ($)	Total annualized costs ($/yr)
1	1	Cannisters and passives (2 analytes)	114,700	659,000
2	1	Cannisters only	12,800	596,000

3.3 Engineering Cost Analysis Summary Results

Table 3-20 below presents a summary of the costs for the proposed HON amendments by emission point and in total. Capital and total annual costs are shown, and total annual costs are shown with and without product recovery. The effect of product recovery on the total annual costs is quite small, as is shown in the table. The total capital cost of the proposed HON amendments is about $440 million, and the total annual cost is about $163 million (with product recovery) and $164 million (without product recovery) in 2021 dollars. The estimation of total capital cost (synonymous with total capital investment) and total annual cost follows the methodology in the EPA Air Pollution Control Cost Manual (EPA, 2017). Estimates of total annual cost includes both operating and maintenance and annualized capital costs (from capital recovery). The inclusion of product recovery reduces the total annual cost by only 0.5 percent (about $900,000, as shown in the table), but its inclusion leads to annual cost savings from controls for heat exchange systems.

Table 3-20: Detailed Costs for the HON Source Category by Emission Point for the Proposed Rule (2021$)

Emission Point	Total Capital Cost ($)	Total Annual Cost ($/yr) Without Recovery Credits	Total Annual Cost ($/yr) With Recovery Credits	Annual Recovery Credits ($/yr)
Flares	$326,443,400	$68,658,000	$68,658,000	$0
Fenceline Monitoring	$9,754,300	$32,055,300	$32,055,300	$0
Pressure Relief Devices	$16,829,400	$7,481,600	$7,481,600	$0
Storage Vessels	$2,191,500	$415,500	$415,500	$0
Storage Vessels - Degassing	$0	$751,500	$751,500	$0
Storage Vessels – Pressure Vessels	$77,700	$72,900	$72,900	$0
Storage Vessels – 240hr Maintenance	$2,637,400	$456,500	$456,500	$0
Maintenance	$0	$94,200	$94,200	$0
Heat Exchange Systems	$783,800	$237,700	-$603,000	$840,800
Process Vents	$1,217,600	$3,149,700	$3,149,700	$0
EtO Risk	$76,517,700	$47,920,100	$47,895,800	$24,300
Dioxins/Furans	$3,920,000	$2,275,000	$2,275,000	$0
Carbon Cannisters	$53,000	$5,000	$5,000	$0
Total	**$440,426,200**	**$163,572,000**	**$162,708,600**	**$870,500**

Tables 3-21 through 3-22 below presents a summary of the costs for the proposed P&R I (Table 3-21) and P&R II (Table 3-22) amendments by emission point and in total. Capital and total annual costs are shown, and total annual costs are shown with and without product recovery. The effect of product recovery on the total annual costs is quite small, as is shown in Table 3-21 for P&R I. The total capital cost of the proposed HON amendments is about $25 million, and the total annual cost is about $15 million (with product recovery) and $15 million (without product recovery) in 2021 dollars. The estimation of total capital cost (synonymous with total capital investment) and total annual cost follows the methodology in the EPA Air Pollution Control Cost Manual (EPA, 2017). Estimates of total annual cost includes both operating and maintenance and annualized capital costs (from capital recovery). The inclusion of product recovery reduces the total annual cost by only 0.2 percent (about $29,000, as shown in the table), but its inclusion leads to annual cost savings from controls for heat exchange systems. For the P&R II proposed amendments, Table 3-22 shows that the total capital cost is about $3 million, with about $2 million in total annual costs and no product recovery.

For the various NSPS proposals, as shown in Table 3-23, the total capital cost for the subpart VVb is about $8 million, with a total annual cost of just over $1 million with product recovery included. With product recovery included, the total annual cost is about $300,000 higher. For the other three NSPS (subpart IIIa, NNNa, RRRa) considered together, the total capital cost is about $24 million, with a total annual cost of about $8 million as shown in Table 3-23. There is no product recovery associated with the controls to meet the requirements for these three NSPS.

Finally, the cumulative total capital cost for the entire proposed action, as shown in Table 3-23, is about $501 million, with a total annual cost for the entire action of $186 million with product recovery. Given that the product recovery is just over $1 million, the total annual cost without product recovery is $187 million. The cumulative product recovery is only about 0.6 percent of the total annual costs.

Engineering cost estimates in this chapter include projections of revenue from product recovery. This is because control options analyzed in this RIA lead to the recovery of chemical products. Recovered chemical product affected by this rulemaking is monetized as recovery credits by multiplying VOC emissions reductions by a VOC credit of $900/ton (2021 dollars).

Because the controls considered lead to product recovery, it is possible for the cost of a control option to be negative once the value of product recovery is considered (the potential annualized costs may be outweighed by the revenue from product recovery). This observation may typically support an assumption that owners of facilities would continue to perform the emissions abatement activity regardless of whether a requirement is in place, because it is in their private self-interest. However, there may be an opportunity cost associated with the installation of environmental controls or implementation of compliance activities (for purposes of mitigating the emission of pollutants) that is not reflected in the control costs. If environmental investment displaces investment in productive capital, the difference between the rate of return on the marginal investment displaced by the mandatory environmental investment is a measure of the opportunity cost of the environmental requirement to the regulated entity. To the extent that any opportunity costs are not added to the control costs, the compliance costs presented above may be underestimated. In addition, the hurdle rate is defined as the minimum rate of return on an investment that a firm would deem acceptable under typical business practices. Thus, if the hurdle rate is higher on average for firms in this industry than the interest rate used in estimating the compliance costs (in this proposed action, 5.5% at the time of this analysis), then these investments in environmental controls may not necessarily be undertaken on average.

From a social perspective, however, the increased financial returns from product recovery accrue to entities somewhere along the chemical product supply chain and should be accounted for in a national-level analysis. An economic argument can be made that, in the long run, no single entity bears the entire burden of compliance costs or fully appropriates the financial gain of the additional revenues associated with chemical product recovery. The change in economic surplus resulting from product recovery may be likely to be spread across different market participants. The simplest and most transparent option for allocating these revenues would be to assign the compliance costs and revenues to a model plant and not make assumptions regarding the allocation of costs and revenues across economic agents.

Table 3-21: Detailed Costs for the P&R I Source Category by Emission Point for the Proposed Rule (2021$)

Emission Point	Total Capital Cost ($)	Total Annual Cost ($/yr) Without Recovery Credits	Total Annual Cost ($/yr) With Recovery Credits	Annual Recovery Credits ($/yr)
Flares	$6,996,100	$1,481,000	$1,481,000	$0
Fenceline Monitoring	$127,600	$1,255,000	$1,255,000	$0
Pressure Relief Devices	$504,400	$128,500	$128,500	$0
Storage Vessels	$130,900	$24,800	$24,800	$0
Storage Vessels – Degassing	$0	$12,300	$12,300	$0
Storage Vessels – Pressure Vessels	$2,200	$2,100	$2,100	$0
Storage Vessels – 240hr Maintenance	$39,500	$6,800	$6,800	$0
Maintenance	$0	$8,700	$8,700	$0
Heat Exchange Systems	$48,300	$9,900	($19,300)	$29,300
Process Vents	$1,009,000	$1,236,900	$1,236,900	$0
CP Risk	$15,948,900	$10,354,500	$10,354,500	$0
Dioxins/Furans	$560,000	$325,000	$325,000	$0
Carbon Cannisters	$27,000	$2,000	$2,000	$0
Total	**$25,393,800**	**$14,847,500**	**$14,818,200**	**$29,200**

Table 3-22: Detailed Costs for the P&R II Source Category by Emission Point for the Proposed Rule (2021$)

Emission Point	Total Capital Cost ($)	Total Annual Cost ($/yr) Without Recovery Credits	Total Annual Cost ($/yr) With Recovery Credits	Annual Recovery Credits ($/yr)
Pressure Relief Devices	$132,700	$33,800	$33,800	$0
Storage Vessels - Degassing	$0	$6,200	$6,200	$0
Maintenance	$0	$2,300	$2,300	$0
Dioxins/Furans	$2,800,000	$1,625,000	$1,625,000	$0
Total	**$2,932,500**	**$1,667,200**	**$1,667,200**	**$0**

Table 3-23: Summary of the Total Costs by Rule ($2021)

Rule	Total Capital Cost ($)	Total Annual Cost ($/yr) Without Recovery Credits	Total Annual Cost ($/yr) With Recovery Credits	Annual Recovery Credits ($/yr)
HON	$440,426,200	$163,572,000	$162,708,600	$870,500
P&R I	$25,393,800	$14,847,500	$14,818,200	$29,200
P&R II	$2,932,500	$1,667,200	$1,667,200	$0
NSPS VVb	$7,706,600	$1,434,200	$1,127,200	$307,000
NSPS IIIa, NNNa, & RRRa	$24,467,300	$5,799,800	$5,799,800	$0
Total	**$500,926,400**	**$187,320,700**	**$186,121,000**	**$1,206,700**

We also show the costs in another way – the current day estimate of the costs of these rules over an analysis time period, and an equivalent annualized value of those costs over the same analysis time period. To facilitate the presentation of these costs, Table 3-24 presents the present value (PV) and equivalent annualized value (EAV) of costs over the analysis time period of 2024-2038 for the cumulative impacts in this rulemaking, discounted to 2023. The present value is a current day estimate of the costs over the analysis time period for this proposed rulemaking, and the equivalent annualized value is the average annual value of these costs whose sum is the PV. These costs include the value of product recovery, which is a very small percentage of the costs for the HON (less than 1 percent of the total annual costs) and cumulatively (also less than 1 percent of the total annual costs). Showing the costs in this way is consistent with OMB Circular A-4.

Table 3-24: Discounted Costs, for the Proposed Amendments to the HON, P&R I, and P&R II NESHAP, and Subparts VVb, IIIa, NNNa, and RRRa NSPS, 2024-2038 (million 2021$, discounted to 2023)

Year	3 percent	7 percent
	Total Annual Cost with Revenue from Product Recovery	Total Annual Cost with Revenue from Product Recovery
2024	$146.7	$126.0
2025	$143.9	$118.7
2026	$140.6	$111.9
2027	$116.7	$89.4
2028	$110.1	$83.6
2029	$110.0	$78.1
2030	$100.7	$63.8
2031	$97.8	$59.6
2032	$94.9	$55.7
2033	$92.2	$52.0
2034	$89.5	$48.6
2035	$87.3	$45.5
2036	$86.9	$42.5
2037	$81.9	$39.7
2038	$79.6	$37.1
PV	**$1,578.8**	**$1,052.1**
EAV	**$132.3**	**$115.5**

Note: Discounted to 2023. Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted. The EAV is an annualized cost for it is an estimate calculated from annual costs across the 15 year analytical timeframe.

Table 3-25 contains a summary of the HAP and VOC emission reductions per year for each proposed rule within this regulatory action, and cumulative (total) estimates. These emission reductions are calculated based on a baseline that include the excess emissions from flares as explained in Chapter 1 of this RIA. Table 3-26 contains a summary of other pollutants emissions changes (increases and decreases), both for criteria other than VOC and climate pollutants, cumulatively for this proposed action.

Table 3-2525: Summary of the HAP and VOC Emission Reductions per Year by Rule

Rule	HAP Emission Reductions (tons per year)	VOC Emission Reductions (tons per year)
HON	5,726	21,142
P&R I	326	763
P&R II	1	1
NSPS VVb	N/A*	340
NSPS IIIa, NNNa, & RRRa	N/A	1,269
Total	**6,053**	**23,515**

*N/A – not available. No HAP reductions are estimated for the proposed NSPS included in this rulemaking.

Table 3-2626: Summary of Emission Changes (Increases or Reductions) Other Than HAP and VOC in Tons per Year, Cumulative and by Proposed Rule*

Pollutant	Total	HON	P&R I	IIIa/NNNa/RRRa
CO	845	714	110	21.51
CO_2	741,102	609,761	115,975	15,366
CH_4	(22,951)	(20,177)	(2,017)	(756)
N_2O	6.86	5.27	1.54	0.06
NO_x	349	272	73	3.96
$PM_{2.5}$	17.4	12.7	4.75	0
SO_2	1.37	0	1.37	0

*A parenthesis denotes emission reductions.

4 BENEFITS OF EMISSIONS REDUCTIONS

4.1 Introduction

The emission controls installed to comply with this proposed action are expected to reduce emissions of volatile organic compounds (VOC) which, in conjunction with NOx and in the presence of sunlight, form ground-level ozone (O_3). This chapter reports the estimated ozone-related benefits of reducing VOC emissions in terms of the number and value of avoided ozone-attributable deaths and illnesses. The potential benefits from reduced ecosystem effects from the reduction in O_3 concentrations are not quantified or monetized here. Time and data limitations for quantifying the effect of this action on biomass loss and foliar injury and the ensuing loss of ecosystem services prevent an assessment of the benefits to ecosystems. The EPA provides a qualitative discussion of the benefits of reducing HAP emissions later in this chapter. Finally, we include an analysis of the climate benefits and disbenefits for this proposed action. We include a presentation of benefits estimates for each of the proposed rules in this rulemaking, and also a cumulative estimate with total benefits for the entire rulemaking.

The PV of the cumulative health benefits for the proposed rules range from $81 million at a 3 percent discount rate to $56 million at a 7 percent discount rate with an EAV of $6.8 million to $6.1 million respectively. The PV of the benefits for the proposed rule range from $730 million at a 3 percent discount rate to $490 million at a 7 percent discount rate with an EAV of $61 to $54 million respectively. Specific estimates of monetized health estimates for each proposed rule can be found later in this chapter in Section 4.5. All estimates are reported in 2021 dollars. The monetized climate benefits of reductions of pollutants such as CH_4 and disbenefits resulting from increasing emissions of CO_2 and N_2O as presented in Chapter 3 are included in this chapter in Section 4.6. The monetized climate benefits and disbenefits are calculated using interim benefit per ton estimates of the social cost of greenhouse gases (SC-GHG) estimates as explained later in this RIA chapter, and are estimated at negative $8.2 million PV at a 3 percent discount rate ($0.7 million EAV).

Health Effects from Exposure to Hazardous Air Pollutants (HAP)

In the subsequent sections, we describe the health effects associated with the main HAP of concern from SOCMI (found within the HON), P&R I, and P&R II source categories: ethylene oxide (Section 4.1.1), chloroprene (Section 4.1.2), benzene (Section 4.1.3), 1,3-butadiene (Section 4.1.4), vinyl chloride (Section 4.1.5), ethylene dichloride (Section 4.1.6), chlorine (Section 4.1.7), maleic anhydride (Section 4.1.8) and acrolein (Section 4.1.9). This proposal is projected to reduce ethylene oxide emissions from HON processes by approximately 58 tons per year (tpy) and reduce chloroprene emissions from Neoprene Production processes in P&R I by approximately 14 tpy. We also estimate that the proposed amendments to the NESHAP would reduce other HAP emissions (excluding ethylene oxide and chloroprene) from the HON, P&R I, and P&R II source categories by approximately 1,123 tpy. We also estimate that the proposed amendments to the NESHAP will reduce excess emissions of HAP from flares in the SOCMI and P&R I source categories by an additional 4,858 tpy. The Agency was unable to estimate HAP emission reductions for the proposed amendments to the NSPS in this rulemaking.

Quantifying and monetizing the economic value of reducing the risk of cancer and non-cancer effects is made difficult by the lack of a central estimate of estimate of cancer and non-cancer risk and estimates of the value of an avoided case of cancer (fatal and non-fatal) and morbidity effects. Due to methodology and data limitations, we did not attempt to monetize the health benefits of reductions in HAP in this analysis. Instead, we are providing a qualitative discussion of the health effects associated with HAP emitted from sources subject to control under the proposed action.

4.1.1 Ethylene oxide

Ethylene oxide is used as a chemical intermediate in the manufacture of ethylene glycol (antifreeze), textiles, detergents, polyurethane foam, solvents, medicine, adhesives, and other products. Health effects from acute (short-term) exposure to ethylene oxide in humans consist mainly of central nervous system depression and irritation of the eyes and mucous membranes. Chronic (long-term) exposure to ethylene oxide in humans can cause irritation of the eyes, skin, nose, throat, and lungs, and damage to the brain and nervous system. There is also some evidence linking ethylene oxide exposure to reproductive effects (ATSDR, 2022). EPA has classified ethylene oxide as carcinogenic to humans by the inhalation route of exposure. Ethylene oxide is a potent carcinogen, and evidence in humans indicates that exposure to ethylene oxide increases the risk of lymphoid cancer and, for females, breast cancer (U.S. EPA, 2016).

4.1.2 Chloroprene

Chloroprene is used primarily in the manufacture of polychloroprene (*e.g.*, Neoprene), which is used to make diverse products requiring chemical, oil, and/or weather resistance (*e.g.*, adhesives, automotive and industrial parts (*e.g.*, belts and hoses), caulks, flame-resistant cushioning). Health effects from acute (short-term) inhalation exposure to high concentrations of chloroprene include headache, irritability, dizziness, insomnia, fatigue, respiratory irritation, cardiac palpitations, chest pains, nausea, dermatitis, and corneal necrosis. Health effects of chronic (long-term) exposure may include fatigue, chest pains, irritability, dermatitis, and hair loss. Other effects reported include changes to the nervous system, changes to the cardiovascular system, and depression of the immune system. There is evidence of an association between occupation exposure to chloroprene and liver cancer. There is also evidence suggesting an association between occupational exposure to chloroprene and lung cancer (U.S. EPA, 2010). Studies in animals have found an increased risk of tumors in multiple organs/organ systems (including reproductive, hepatic, respiratory, gastrointestinal, dermal and ocular). The EPA has classified chloroprene as likely to be carcinogenic to humans (U.S. EPA, 2010).

4.1.3 Benzene

Benzene is used as a constituent in motor fuels and is found in gasoline service station and motor vehicle exhaust emissions into air. Acute effects of benzene inhalation exposure in humans include neurological symptoms such as drowsiness, dizziness, headaches, and unconsciousness. Exposure to benzene vapor can cause eye, skin, and upper respiratory tract irritation. Chronic exposure to benzene is associated with blood disorders, such as preleukemia and aplastic anemia (ATSDR, 2007a). The EPA's Integrated Risk Information System (IRIS) database lists benzene as a known human carcinogen by all routes of exposure. IRIS found a causal relationship between benzene exposure and acute lymphocytic leukemia and a suggestive relationship between benzene exposure and chronic non-lymphocytic leukemia and chronic lymphocytic leukemia (U.S. EPA, 2000). IARC has also determined that benzene is a human carcinogen (IARC, 2018).

4.1.4 1,3-Butadiene

1,3-Butadiene is used in the production of styrene-butadiene rubber, plastics, and thermoplastic resins. A variety of reproductive and developmental effects have been observed in mice exposed to 1,3-butadiene by inhalation (ATSDR, 2012). There are no human data on reproductive or developmental effects (ATSDR, 2012). Epidemiological studies of workers in rubber plants have shown an association between 1,3-butadiene exposure and increased incidence of leukemia (U.S. EPA, 2002). Animal studies have reported tumors at various sites from 1,3-butadiene exposure. EPA has classified 1,3-butadiene as carcinogenic to humans by the inhalation route of exposure. (U.S. EPA, 2002).

4.1.5 Ethylene dichloride (1,2-dichloroethane)

Ethylene dichloride is primarily used in the production of vinyl chloride as well as other chemicals. Inhalation of concentrated ethylene dichloride vapor can induce effects on the human nervous system, liver, and kidneys, as well as respiratory distress and cardiac arrhythmia. No information is available on the chronic effects of ethylene dichloride in humans. In animal studies, chronic (long-term) inhalation exposure to ethylene dichloride has been observed to cause effects on the liver and kidneys. Decreased fertility and increased embryo mortality have been observed in inhalation studies of rats (ATSDR, 1992). Epidemiological studies are not conclusive regarding the carcinogenic effects of ethylene dichloride, due to concomitant exposure to other chemicals. Following treatment by gavage (experimentally placing the chemical in the stomach), several tumor types have been induced in rats and mice. An increased incidence of lung papillomas has been reported in mice after topical application. EPA has classified ethylene dichloride as a Group B2, probable human carcinogen (U.S. EPA, 1999).

4.1.6 Vinyl chloride

Most of the vinyl chloride produced is used to make polyvinyl chloride (PVC) plastic and vinyl products. Acute (short-term) exposure to high levels of vinyl chloride in air has resulted in central nervous system (CNS) effects, such as dizziness, drowsiness, and headaches in humans. Chronic (long-term) exposure to vinyl chloride through inhalation and oral exposure in humans has resulted in CNS effects and liver damage. Animal studies have reported effects on the liver, kidney, and CNS from chronic exposure to vinyl chloride (ATSDR, 2006). Vinyl chloride exposure via inhalation has been shown to increase the risk of a rare form of liver cancer, angiosarcoma of the liver, in humans. EPA has concluded that vinyl chloride is carcinogenic to humans by the inhalation and oral routes of exposure, and highly likely to be carcinogenic by the dermal route of exposure (U.S. EPA, 2000).

4.1.7 Chlorine

Chlorine (Cl_2) is a gas that is a potent irritant to the eyes and respiratory tract. Exposure to low levels of chlorine can result in nose, throat, and eye irritation. At higher levels, breathing chlorine gas may result in changes in breathing rate and coughing, and damage to the lungs. Studies in volunteers exposed to controlled concentrations of chlorine indicate that exposures to 1–3 ppm produce mild irritation of the nose that can be tolerated for about 1 hour; 5 ppm may produce eye irritation; headache and throat irritation may occur at concentrations of 5–15 ppm; 30 ppm produces immediate chest pain, nausea and vomiting, dyspnea, and cough; and 40–60 ppm produces toxic pneumonitis and pulmonary edema. Concentrations in typical human exposure environments are much lower than these levels unless an accident involving chlorine takes place nearby (*e.g.,* a leak from a chlorine tank or a leak from a facility that produces or uses chlorine). Chronic (long-term) exposure to chlorine gas in workers has resulted in respiratory effects, including eye and throat irritation and airflow obstruction (ATSDR, 2010). EPA has not assessed chlorine for carcinogenicity under the IRIS program (U.S. EPA, 1994).

4.1.8 Maleic anhydride

Maleic anhydride is used in the formulation of resins. Exposure to maleic anhydride may occur from accidental releases to the environment or in workplaces where it is produced or used. Acute (short-term) inhalation exposure of humans to maleic anhydride has been observed to cause irritation of the respiratory tract and eye irritation. Chronic (long-term) exposure to maleic anhydride has been observed to cause chronic bronchitis, asthma-like attacks, and upper respiratory tract and eye irritation in workers. In some people, allergies have developed so that lower concentrations can no longer be tolerated. Kidney effects were observed in rats chronically exposed to maleic anhydride via gavage (CalEPA, 2001). EPA has not assessed maleic anhydride for carcinogenicity under the IRIS program (U.S. EPA, 1988).

4.1.9 Acrolein

Acrolein is primarily used as an intermediate in the synthesis of acrylic acid and as a biocide. It is toxic to humans following inhalation, oral or dermal exposures. Acute (short-term) inhalation exposure may result in upper respiratory tract irritation and congestion. The major effects from chronic (long-term) inhalation exposure to acrolein in humans and animals consist of general respiratory congestion and eye, nose, and throat irritation (ATSDR, 2007b). The EPA IRIS program noted, in 2003, that the potential carcinogenicity of acrolein cannot be determined because the existing data are inadequate for an assessment of human carcinogenic potential for either the oral or inhalation route of exposure (U.S. EPA, 2003).

4.1.10 Other Hazardous Air Pollutants (HAP)

In addition to the compounds described above, other toxic compounds might be affected by this action. Information regarding the health effects of those compounds can be found in *Health Effects Notebook for Hazardous Air Pollutants* (at https://www.epa.gov/haps/health-effects-notebook-hazardous-air-pollutants) and in the EPA Integrated Risk Information System (IRIS) database (at https://iris.epa.gov/AtoZ/?list_type=alpha).

4.2 Ozone-related Human Health Benefits

This section summarizes the EPA's approach to estimating the incidence and economic value of the ozone-related benefits estimated for this action. The Regulatory Impact Analysis (RIA) Final Revised Cross-State Air Pollution Rule (U.S. EPA, 2021) and its corresponding Technical Support Document Estimating $PM_{2.5}$ -and Ozone – Attributable Health Benefits (TSD) (U.S. EPA, 2021) provide a full discussion of the EPA's approach for quantifying the incidence and value of estimated air pollution-related health impacts. In these documents, the reader can find the rationale for selecting the health endpoints quantified; the demographic, health and economic data applied in the environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE); modeling assumptions; and the EPA's techniques for quantifying uncertainty.

Implementing this action will affect the distribution of ozone concentrations throughout the U.S.; this includes locations both meeting and exceeding the NAAQS for O_3. This RIA estimates avoided O_3-related health impacts that are distinct from those reported in the RIAs for the O_3 NAAQS (U.S. EPA, 2015). The O_3 NAAQS RIAs hypothesize, but do not predict, the benefits and costs of strategies that states may choose to enact when implementing a revised NAAQS; these costs and benefits are illustrative and cannot be added to the costs and benefits of policies that prescribe specific emission control measures.

4.2.1 Estimating Ozone Related Health Impacts

We estimate the quantity and economic value of air pollution-related effects by estimating counts of air pollution-attributable cases of adverse health outcomes, assigning dollar values to these counts, and assuming that each outcome is independent of one another. We construct these estimates by adapting primary research—specifically, air pollution epidemiology studies and economic value studies—from similar contexts. This approach is sometimes referred to as "benefits transfer." Below we describe the procedure we follow for: (1) selecting air pollution health endpoints to quantify; (2) calculating counts of air pollution effects using a health impact function; (3) specifying the health impact function with concentration-response parameters drawn from the epidemiological literature.

4.2.2 Selecting air pollution health endpoints to quantify

As a first step in quantifying O_3-related human health impacts, the EPA consults the *Integrated Science Assessment for Ozone* (Ozone ISA) (U.S. EPA, 2020) as summarized in the TSD for the Final Revised Cross State Air Pollution Rule Update (U.S. EPA, 2021). This document synthesizes the toxicological, clinical, and epidemiological evidence to determine whether each pollutant is causally related to an array of adverse human health outcomes associated with either acute (*i.e.*, hours or days-long) or chronic (*i.e.*, years-long) exposure. For each outcome, the ISA reports this relationship to be causal, likely to be causal, suggestive of a causal relationship, inadequate to infer a causal relationship, or not likely to be a causal relationship.

In brief, the ISA for ozone found short-term (less than one month) exposures to ozone to be causally related to respiratory effects, a "likely to be causal" relationship with metabolic effects and a "suggestive of, but not sufficient to infer, a causal relationship" for central nervous system effects, cardiovascular effects, and total mortality. The ISA reported that long-term exposures (one month or longer) to ozone are "likely to be causal" for respiratory effects including respiratory mortality, and a "suggestive of, but not sufficient to infer, a causal relationship" for cardiovascular effects, reproductive effects, central nervous system effects, metabolic effects, and total mortality.

The EPA estimates the incidence of air pollution effects for those health endpoints listed above where the ISA classified the impact as either causal or likely-to-be-causal. Table 4-1 reports the effects we quantified and those we did not quantify in this RIA. The list of benefit categories not quantified shown in that table is not exhaustive. And, among the effects we quantified, we might not have been able to completely quantify either all human health impacts or economic values. The table below omits any welfare effects such as biomass loss and foliar injury. These effects are described in Chapter 7 of the Ozone NAAQS RIA (2015).

Table 4-1: Human Health Effects of Ambient Ozone and whether they were Quantified and/or Monetized in this RIA.

Category	Effect	Effect Quantified	Effect Monetized	More Information
Mortality from exposure to ozone	Premature respiratory mortality from short-term exposure (0-99)	✓	✓	Ozone ISA[1]
	Premature respiratory mortality from long-term exposure (age 30–99)	✓	✓	Ozone ISA
Nonfatal morbidity from exposure to ozone	Hospital admissions—respiratory (ages 65-99)	✓	✓	Ozone ISA
	Emergency department visits—respiratory (ages 0-99)	✓	✓	Ozone ISA
	Asthma onset (0-17)	✓	✓	Ozone ISA
	Asthma symptoms/exacerbation (asthmatics age 5-17)	✓	✓	Ozone ISA
	Allergic rhinitis (hay fever) symptoms (ages 3-17)	✓	✓	Ozone ISA
	Minor restricted-activity days (age 18–65)	✓	✓	Ozone ISA
	School absence days (age 5–17)	✓	✓	Ozone ISA
	Decreased outdoor worker productivity (age 18–65)	—	—	Ozone ISA[2]
	Metabolic effects (*e.g.*, diabetes)	—	—	Ozone ISA[2]
	Other respiratory effects (*e.g.*, premature aging of lungs)	—	—	Ozone ISA[2]
	Cardiovascular and nervous system effects	—	—	Ozone ISA[2]
	Reproductive and developmental effects	—	—	Ozone ISA[2]

[1] We assess these benefits qualitatively due to data and resource limitations for this analysis. In other analyses we quantified these effects as a sensitivity analysis.

[2] We assess these benefits qualitatively because we do not have sufficient confidence in available data or methods.

4.2.3 Quantifying Cases of Ozone-Attributable Premature Mortality

Mortality risk reductions account for the majority of monetized ozone-related benefits. For this reason, this subsection and the following provide a brief background of the scientific assessments that underly the quantification of these mortality risks and identifies the risk studies used to quantify them in this RIA for ozone. As noted above, the *Estimating $PM_{2.5}$- and Ozone-Attributable Health Benefits* TSD describes fully the Agency's approach for quantifying the number and value of ozone air pollution-related impacts, including additional discussion of how the Agency selected the risk studies used to quantify them in this RIA. The TSD also includes additional discussion of the assessments that support quantification of these mortality risk than provide here.

In 2008, the National Academies of Science (NRC 2008) issued a series of recommendations to EPA regarding the procedure for quantifying and valuing ozone-related mortality due to short-term exposures. Chief among these was that "…short-term exposure to ambient ozone is likely to contribute to premature deaths" and the committee recommended that "ozone-related mortality be included in future estimates of the health benefits of reducing ozone exposures…" The NAS also recommended that "…the greatest emphasis be placed on the multicity and [National Mortality and Morbidity Air Pollution Studies (NMMAPS)] …studies without exclusion of the meta-analyses" (NRC 2008). Prior to the 2015 Ozone NAAQS RIA, the Agency estimated ozone-attributable premature deaths using an NMMAPS-based analysis of total mortality (Bell et al. 2004), two multi-city studies of cardiopulmonary and total mortality (Huang et al. 2004; Schwartz 2005) and effect estimates from three meta-analyses of non-accidental mortality (Bell et al. 2005; Ito et al. 2005; Levy et al. 2005). Beginning with the 2015 Ozone NAAQS RIA, the Agency began quantifying ozone-attributable premature deaths using two newer multi-city studies of non-accidental mortality (Smith et al. 2009; Zanobetti and Schwartz 2008) and one long-term cohort study of respiratory mortality (Jerrett et al. 2009). The 2020 Ozone ISA included changes to the causality relationship determinations between short-term exposures and total mortality, as well as including more recent epidemiologic analyses of long-term exposure effects on respiratory mortality (U.S. EPA, 2020). In this RIA, as described in the corresponding TSD, two estimates of ozone-attributable respiratory deaths from short-term exposures are estimated using the risk estimate parameters from Zanobetti et al. (2008) and Katsouyanni et al. (2009). Ozone-attributable respiratory deaths from long-term exposures are estimated using Turner et al. (2016). Due to time and resource limitations, we were unable to reflect the warm season defined by Zanobetti et al. (2008) as June-August. Instead, we apply this risk estimate to our standard warm season of May-September.

4.3 Approach to Estimating PM2.5-related Human Health Benefits

This section summarizes the EPA's approach to estimating the incidence and economic value of the $PM_{2.5}$-related benefits estimated for this rule. The Regulatory Impact Analysis for the Proposed National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-Fired Electric Utility Steam Generating Units Review of the Residual Risk and Technology Review (U.S. EPA, 2023a) and its corresponding Technical Support Document Estimating $PM_{2.5}$ -and

Ozone – Attributable Health Benefits (TSD) (U.S. EPA, 2023b) provide a full discussion of the EPA's approach for quantifying the incidence and value of estimated air pollution-related health impacts. In these documents, the reader can find the rationale for selecting the health endpoints quantified; the demographic, health and economic data applied in the environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE); modeling assumptions; and the EPA's techniques for quantifying uncertainty.

Implementing this rule will affect the distribution of PM2.5 concentrations throughout the U.S.; this includes locations both meeting and exceeding the NAAQS for PM and ozone. This RIA estimates avoided PM2.5-related health impacts that are distinct from those reported in the RIA for the PM NAAQS (U.S. EPA, 2022). The PM2.5 NAAQS RIA hypothesizes, but does not predict, the benefits and costs of strategies that States may choose to enact when implementing a revised NAAQS; these costs and benefits are illustrative and cannot be added to the costs and benefits of policies that prescribe specific emission control measures.

We estimate the quantity and economic value of air pollution-related effects by estimating counts of air pollution-attributable cases of adverse health outcomes, assigning dollar values to these counts, and assuming that each outcome is independent of one another. We construct these estimates by adapting primary research—specifically, air pollution epidemiology studies and economic value studies—from similar contexts. This approach is sometimes referred to as "benefits transfer." Below we describe the procedure we follow for: (1) selecting air pollution health endpoints to quantify; (2) calculating counts of air pollution effects using a health impact function; (3) specifying the health impact function with concentration-response parameters drawn from the epidemiological literature.

4.3.1 Selecting Air Pollution Health Endpoints to Quantify

As a first step in quantifying $PM_{2.5}$-related human health impacts, the EPA consults the *Integrated Science Assessment for Particulate Matter* (PM ISA) (U.S. EPA, 2019a) as summarized in the TSD for the Final Revised Cross State Air Pollution Rule Update (U.S. EPA, 2021b). This document synthesizes the toxicological, clinical, and epidemiological evidence to determine whether each pollutant is causally related to an array of adverse human health outcomes associated with either acute (*i.e.*, hours or days-long) or chronic (*i.e.*, years-long) exposure. For each outcome, the ISA reports this relationship to be causal, likely to be causal, suggestive of a causal relationship, inadequate to infer a causal relationship, or not likely to be a causal relationship.

The ISA for $PM_{2.5}$ found acute exposure to $PM_{2.5}$ to be causally related to cardiovascular effects and mortality (*i.e.*, premature death), and respiratory effects as likely-to-be-causally related. The ISA identified cardiovascular effects and total mortality as being causally related to long-term exposure to $PM_{2.5}$ and respiratory effects as likely-to-be-causal; and the evidence was suggestive of a causal relationship for reproductive and developmental effects as well as cancer, mutagenicity, and genotoxicity.

The EPA estimates the incidence of air pollution effects for those health endpoints listed above where the ISA classified the impact as either causal or likely-to-be-causal. Table 4-2 reports the effects we quantified and those we did not quantify in this RIA. The list of benefit categories not quantified shown in that table is not exhaustive. Among the effects we quantified, we might not have been able to completely quantify either all human health impacts or economic values. The table below omits health effects associated with SO_2 and NO_2, and any welfare effects such as acidification and nutrient enrichment. These effects are described in the Technical Support Document "Estimating $PM_{2.5}$- and Ozone-Related Benefits", which details the approach EPA followed for selecting and quantifying PM-attributable effects (U.S. EPA, 2021).

In December of 2022, EPA published the Regulatory Impact Analysis (RIA) for the proposed Particulate Matter National Ambient Air Quality Standards (U.S.EPA, 2022). EPA quantified the PM-related benefits of this rule prior to publishing of the proposed PM NAAQS RIA. For this reason, the PM-related benefits reported in this RIA reflect methods consistent with an earlier version of the TSD (U.S. EPA, 2021). Though the methodology employed in this RIA is largely consistent with the PM NAAQS RIA, here we estimate PM-attributable mortality using concentration-response parameters that differ from those applied in the PM NAAQS RIA. Specifically, we estimate PM-attributable deaths using concentration-response parameters from the Di et al. (2017) and Turner et al. (2016) long-term exposure studies of the Medicare and American Cancer Society cohorts, respectively. By contrast, the PM NAAQS RIA quantified PM-attributable mortality using concentration response parameters from the Wu et al. (2020) and Pope et al. (2019) long-term exposure studies of the Medicare and National Health Interview Survey cohorts, respectively.

Table 4-2: Human Health Effects of $PM_{2.5}$ and whether they were Quantified and/or Monetized in this RIA.

Category	Effect	Effect Quantified	Effect Monetized	More Information
Premature mortality from exposure to $PM_{2.5}$	Adult premature mortality from long-term exposure (age 65-99 or age 30-99)	✓	✓	PM ISA
	Infant mortality (age <1)	✓	✓	PM ISA
Nonfatal morbidity from exposure to $PM_{2.5}$	Heart attacks (age > 18)	✓	✓[1]	PM ISA
	Hospital admissions—cardiovascular (ages 65-99)	✓	✓	PM ISA
	Emergency department visits— cardiovascular (age 0-99)	✓	✓	PM ISA
	Hospital admissions—respiratory (ages 0-18 and 65-99)	✓	✓	PM ISA
	Emergency room visits—respiratory (all ages)	✓	✓	PM ISA
	Cardiac arrest (ages 0-99; excludes initial hospital and/or emergency department visits)	✓	✓[1]	PM ISA
	Stroke (ages 65-99)	✓	✓[1]	PM ISA
	Asthma onset (ages 0-17)	✓	✓	PM ISA
	Asthma symptoms/exacerbation (6-17)	✓	✓	PM ISA
	Lung cancer (ages 30-99)	✓	✓	PM ISA
	Allergic rhinitis (hay fever) symptoms (ages 3-17)	✓	✓	PM ISA
	Lost work days (age 18-65)	✓	✓	PM ISA
	Minor restricted-activity days (age 18-65)	✓	✓	PM ISA
	Hospital admissions—Alzheimer's disease (ages 65-99)	✓	✓	PM ISA
	Hospital admissions—Parkinson's disease (ages 65-99)	✓	✓	PM ISA
	Other cardiovascular effects (*e.g.*, other ages)	—	—	PM ISA[2]
	Other respiratory effects (*e.g.*, pulmonary function, non-asthma ER visits, non-bronchitis chronic diseases, other ages and populations)	—	—	PM ISA[2]
	Other nervous system effects (*e.g.*, autism, cognitive decline, dementia)	—	—	PM ISA[2]
	Metabolic effects (*e.g.*, diabetes)	—	—	PM ISA[2]
	Reproductive and developmental effects (*e.g.*, low birth weight, pre-term births, etc.)	—	—	PM ISA[2]
	Cancer, mutagenicity, and genotoxicity effects	—	—	PM ISA[2]

[1] We assess these benefits qualitatively due to data and resource limitations for this analysis. In other analyses we quantified these effects as a sensitivity analysis.

[2] We assess these benefits qualitatively because we do not have sufficient confidence in available data or methods.

4.3.2 Quantifying Cases of PM2.5-Attributable Premature Death

This section summarizes our approach to estimating the incidence and economic value of the $PM_{2.5}$-related ancillary co-benefits estimated for this rule. A full discussion of EPA's approach to selecting human health endpoints, epidemiologic studies and economic unit values can be found in the Technical Support Document (TSD) supporting the final Cross-State Update rule (U.S. EPA, 2021b). The user manual for the environmental Benefits Mapping and Analysis Program-Community Edition (BenMAP-CE) program[16] separately details EPA's approach for quantifying and monetizing PM-attributable effects in the BenMAP-CE program. In these documents the reader can find the rationale for selecting health endpoints to quantify; the demographic, health and economic data we apply within BenMAP-CE; modeling assumptions; and our techniques for quantifying uncertainty.

The PM ISA, which was reviewed by the Clean Air Scientific Advisory Committee of the EPA's Science Advisory Board (U.S. EPA-SAB-CASAC, 2019), concluded that there is a causal relationship between mortality and both long-term and short-term exposure to $PM_{2.5}$ based on the body of scientific evidence. The PM ISA also concluded that the scientific literature supports the use of a no-threshold log-linear model to portray the PM-mortality concentration-response relationship while recognizing potential uncertainty about the exact shape of the concentration-response function. The PM ISA identified epidemiologic studies that examined the potential for a population-level threshold to exist in the concentration-response relationship. Based on such studies, the ISA concluded that "…the evidence from recent studies reduce uncertainties related to potential co-pollutant confounding and continues to provide strong support for a linear, no-threshold concentration-response relationship" (U.S. EPA, 2019a). Consistent with this evidence, the EPA historically has estimated health impacts above and below the prevailing NAAQS.[17]

Following this approach, we report the estimated $PM_{2.5}$-related benefits (in terms of both health impacts and monetized values) calculated using a log-linear concentration-response function that quantifies risk from the full range of simulated $PM_{2.5}$ exposures (U.S. EPA, 2021b). As noted in the preamble to the 2020 PM NAAQS final rule, the "health effects can occur over the entire distributions of ambient $PM_{2.5}$ concentrations evaluated, and epidemiological studies do not identify a population-level threshold below which it can be concluded with confidence

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[16] BenMAP-CE Manual and Appendices, 2022. https://www.epa.gov/benmap/benmap-ce-manual-and-appendices

[17] The Federal Register Notice for the 2012 PM NAAQS notes that "[i]n reaching her final decision on the appropriate annual standard level to set, the Administrator is mindful that the CAA does not require that primary standards be set at a zero-risk level, but rather at a level that reduces risk sufficiently so as to protect public health, including the health of at-risk populations, with an adequate margin of safety. On balance, the Administrator concludes that an annual standard level of 12 ug/m3 would be requisite to protect the public health with an adequate margin of safety from effects associated with long- and short-term $PM_{2.5}$ exposures, while still recognizing that uncertainties remain in the scientific information."

that PM-associated health effects do not occur."[18] In general, we are more confident in the size of the risks we estimate from simulated $PM_{2.5}$ concentrations that coincide with the bulk of the observed PM concentrations in the epidemiological studies that are used to estimate the benefits. Likewise, we are less confident in the risk we estimate from simulated $PM_{2.5}$ concentrations that fall below the bulk of the observed data in these studies (U.S. EPA, 2021b). As described further below, we lacked the air quality modeling simulations to perform such an analysis for this proposed rule and thus report the total number of avoided $PM_{2.5}$-related premature deaths using the traditional log-linear no-threshold model noted above.

4.4 Economic Valuation

After quantifying the change in adverse health impacts, we estimate the economic value of these avoided impacts. Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health effects by a small amount for a large population. Therefore, the appropriate economic measure is willingness to pay (WTP) for changes in risk of a health effect. For some health effects, such as hospital admissions, WTP estimates are generally not available, so we use the cost of treating or mitigating the effect. These cost-of-illness (COI) estimates generally (although not necessarily in every case) understate the true value of reductions in risk of a health effect. They tend to reflect the direct expenditures related to treatment but not the value of avoided pain and suffering from the health effect. The unit values applied in this analysis are provided in Section 5.1 of the TSD for the Revised Cross State Update rule (U.S. EPA, 2021).

Avoided premature deaths account for 95 percent of monetized ozone-related benefits and 98 percent of monetized PM-related benefits. The economics literature concerning the appropriate method for valuing reductions in premature mortality risk is still developing. The value for the projected reduction in the risk of premature mortality is the subject of continuing discussion within the economics and public policy analysis community. Following the advice of the Scientific Advisory Board's (SAB) Environmental Economics Advisory Committee (SAB-EEAC), the EPA currently uses the value of statistical life (VSL) approach in calculating estimates of mortality benefits, because we believe this calculation provides the most reasonable

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[18] https://www.govinfo.gov/content/pkg/FR-2020-12-18/pdf/2020-27125.pdf

single estimate of an individual's WTP for reductions in mortality risk (U.S. EPA–SAB, 2000). The VSL approach is a summary measure for the value of small changes in mortality risk experienced by a large number of people.

The EPA continues work to update its guidance on valuing mortality risk reductions and consulted several times with the SAB-EEAC on the issue. Until updated guidance is available, the EPA determined that a single, peer-reviewed estimate applied consistently best reflects the SAB-EEAC advice it has received. Therefore, the EPA applies the VSL that was vetted and endorsed by the SAB in the *Guidelines for Preparing Economic Analyses* while the EPA continues its efforts to update its guidance on this issue (U.S. EPA, 2016). This approach calculates a mean value across VSL estimates derived from 26 labor market and contingent valuation studies published between 1974 and 1991. The mean VSL across these studies is $10.7 million ($2016).[19]

The EPA is committed to using scientifically sound, appropriately reviewed evidence in valuing changes in the risk of premature death and continues to engage with the SAB to identify scientifically sound approaches to update its mortality risk valuation estimates. Most recently, the Agency proposed new meta-analytic approaches for updating its estimates which were subsequently reviewed by the SAB-EEAC. The EPA is taking the SAB's formal recommendations under advisement (U.S. EPA, 2017b).

Because short-term ozone-related premature mortality occurs within the analysis year, the estimated ozone-related benefits are identical for all discount rates. When valuing changes in ozone-attributable deaths using the Turner et al. (2016) study, we follow advice provided by the Health Effects Subcommittee of the SAB, which found that "…there is no evidence in the literature to support a different cessation lag between ozone and particulate matter. The HES therefore recommends using the same cessation lag structure and assumptions as for particulate matter when utilizing cohort mortality evidence for ozone" (U.S. EPA-SAB 2010).

These estimated health benefits do not account for the influence of future changes in the climate on ambient concentrations of pollutants (USGCRP 2016). For example, recent research suggests that future changes to climate may create conditions more conducive to forming ozone.

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[19] In 1990$, this base VSL is $4.8 million. In 2016$, this base VSL is $10.7 million.

The estimated health benefits also do not consider the potential for climate-induced changes in temperature to modify the relationship between ozone and the risk of premature mortality (Jhun et al. 2014; Ren et al. 2008a, 2008b).

4.4.1 Benefit-per-Ton Estimates

The EPA did not conduct air quality modeling for this rule. Rather, we quantified the value of reducing PM concentrations using a "benefit-per-ton" approach, due to the relatively small number of facilities and the fact that these facilities are located in a discrete location. Specifically, EPA believes that the emissions reductions due to this rule are small and because we cannot be confident of the location of new facilities under the NSPS, EPA elected to use the benefit-per-ton. EPA did not expect full air quality modeling to show a significant difference between the policy and baseline model runs. Instead, we used a "benefit-per-ton" (BPT) approach to estimate the benefits of this rulemaking. These BPT estimates provide the total monetized human health benefits (the sum of premature mortality and premature morbidity) of reducing one ton of the VOC precursor for ozone from a specified source. Specifically, in this analysis, we multiplied the estimates from the "Synthetic Organic Chemicals" sector by the corresponding emission reductions. The method used to derive these estimates is described in the BPT Technical Support Document (BPT TSD) on *Estimating the Benefit per Ton of Reducing Directly-Emitted $PM_{2.5}$, $PM_{2.5}$ Precursors and Ozone Precursors from 21 Sectors* and its precursors from 21 sectors (U.S. EPA, 2021). As noted above, we were unable to quantify the value of changes in exposure to HAP, CO, and NO_2.

As noted below in the characterization of uncertainty, all BPT estimates have inherent limitations. Specifically, all national-average BPT estimates reflect the geographic distribution of the modeled emissions, which may not exactly match the emission reductions that would occur due to the action, and they may not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors for any specific location. In an effort to address this limitation we have generated regional level BPTs for the synthetic organic chemicals sector. Given sector specific air quality modeling and the small changes in emissions considered in this action, the difference in the quantified health benefits that result from the BPT approach compared with if EPA had used a full-form air quality model should be minimal.

The EPA systematically compared the changes in benefits, and concentrations where available, from its BPT technique and other reduced-form techniques to the changes in benefits and concentrations derived from full-form photochemical model representation of a few different specific emissions scenarios. Reduced-form tools are less complex than the full air quality modeling, requiring less agency resources and time. That work, in which we also explore other reduced form models is referred to as the "Reduced Form Tool Evaluation Project" (Project), began in 2017, and the initial results were available at the end of 2018. The Agency's goal was to create a methodology by which investigators could better understand the suitability of alternative reduced-form air quality modeling techniques for estimating the health impacts of criteria pollutant emissions changes in the EPA's benefit-cost analysis, including the extent to which reduced-form models may over- or under-estimate benefits (compared to full-scale modeling) under different scenarios and air quality concentrations. The EPA Science Advisory Board (SAB) convened a panel to review this report.[20] In particular, the SAB assessed the techniques the Agency used to appraise these tools; the Agency's approach for depicting the results of reduced-form tools; and steps the Agency might take for improving the reliability of reduced-form techniques for use in future Regulatory Impact Analyses (RIAs).

The scenario-specific emission inputs developed for this project are currently available online. The study design and methodology are described in the final report summarizing the results of the project (IEc, 2019. *Evaluating Reduced-Form Tools for Estimating Air Quality Benefits. Final Report*). Results of this project found that total $PM_{2.5}$ BPT values were within approximately 10 percent of the health benefits calculated from full-form air quality modeling when analyzing the pulp and paper sector, a sector used as an example for evaluating the application of the new methodology in the final report. The ratios for individual PM species varied, and the report found that the ratio for the directly emitted $PM_{2.5}$ for the pulp and paper sector was 0.7 for the BPT approach compared to 1.0 for full-form air quality modeling combined with BenMAP. This provides some initial understanding of the uncertainty which is associated with using the BPT approach instead of full-form air quality modeling.

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[20] 85 FR 23823. April 29, 2020.

4.4.2 Ozone Vegetation Effects

Exposure to ozone has been found to be associated with a wide array of vegetation and ecosystem effects in the published literature (U.S. EPA, 2020). Sensitivity to ozone is highly variable across species, with over 66 vegetation species identified as "ozone-sensitive," many of which occur in state and national parks and forests. These effects include those that cause damage to, or impairment of, the intended use of the plant or ecosystem. Such effects are considered adverse to public welfare and can include reduced growth and/or biomass production in sensitive trees, reduced yield and quality of crops, visible foliar injury, changed to species composition, and changes in ecosystems and associated ecosystem services.

4.4.3 Ozone Climate Effects

Ozone is a well-known short-lived climate forcing GHG (U.S. EPA, 2013). Stratospheric ozone (the upper ozone layer) is beneficial because it protects life on Earth from the sun's harmful ultraviolet (UV) radiation. In contrast, tropospheric ozone (ozone in the lower atmosphere) is a harmful air pollutant that adversely affects human health and the environment and contributes significantly to regional and global climate change. Due to its short atmospheric lifetime, tropospheric ozone concentrations exhibit large spatial and temporal variability (U.S. EPA, 2009b). The IPCC AR5 estimated that the contribution to current warming levels of increased tropospheric ozone concentrations resulting from human methane, NO_X, and VOC emissions was 0.5 W/m^2, or about 30 percent as large a warming influence as elevated CO_2 concentrations. This quantifiable influence of ground level ozone on climate leads to increases in global surface temperature and changes in hydrological cycles.

4.5 Ozone-, NOx- and $PM_{2.5}$ -Related Benefits Results

Table 4-3, 4-4 and 4-5 list the estimated VOC-, NOx- and $PM_{2.5}$-related benefits per ton applied in this national level analysis. Benefits are estimated using two alternative concentration-response parameters from three epidemiologic studies when quantifying both PM2.5 and ozone-related mortality (Di et al. 2017, Turner et al. 2016 and Katsouyanni et al. 2009) These results are discounted at 3 and 7 percent for a 2021 currency year. For all estimates, we summarize the monetized health benefits using discount rates of 3 percent and 7 percent for the 15-year analysis period of this rule discounted back to 2023 rounded to 2 significant figures as presented in Table

4-5. The PV of the benefits for the proposed rulemaking range from $81 million at a 3 percent discount rate to $56 million at a 7 percent discount rate with an EAV of $6.8 million to $6.1 million, respectively. The PV of the benefits for the proposed rulemaking range from $730 million at a 3 percent discount rate to $490 million at a 7 percent discount rate with an EAV of $61 to $54 million, respectively. All estimates are reported in 2021 dollars. Undiscounted benefits are presented by year for the proposed and less stringent alternative options in Table 4-4 and Table 4-5. For the full set of underlying calculations see the "Final HONSOCMI Benefits workbook," available in the docket for the proposal.

Table 4-3: Synthetic Organic Chemicals: Benefit per Ton Estimates of Ozone-Attributable Premature Mortality and Illness for the Proposal, 2024-2038 (2021$)

	Discount Rate					
Year	**3 Percent**			**7 Percent**		
2025	$686	and	$5,892	$617	and	$5,285
2030	$731	and	$6,487	$659	and	$5,817
2035	$771	and	$7,136	$699	and	$6,391
2040	$805	and	$7,668	$731	and	$6,881

Note: The standard reporting convention for EPA benefits is to round all results to two significant figures. Here, we report all significant figures so that readers may reproduce the results reported below.

Table 4-4: Synthetic Organic Chemicals: Benefit per Ton Estimates of NOx-Attributable Premature Mortality and Illness for the Proposal, 2024-2038(2021$)

	Discount Rate					
Year	**3 Percent**			**7 Percent**		
2025	$18,079	and	$18,398	$16,271	and	$16,590
2030	$19,355	and	$20,206	$17,441	and	$18,185
2035	$21,163	and	$22,652	$19,036	and	$20,312
2040	$22,758	and	$24,672	$20,525	and	$22,226

Note: The standard reporting convention for EPA benefits is to round all results to two significant figures. Here, we report all significant figures so that readers may reproduce the results reported below.

Table 4-5: Synthetic Organic Chemicals: Benefit per Ton Estimates of NOx-Attributable Premature Mortality and Illness for the Proposal, 2024-2038(2021$)

	Discount Rate					
Year	3 Percent			7 Percent		
2025	$18,079	and	$18,398	$16,271	and	$16,590
2030	$19,355	and	$20,206	$17,441	and	$18,185
2035	$21,163	and	$22,652	$19,036	and	$20,312
2040	$22,758	and	$24,672	$20,525	and	$22,226

Note: The standard reporting convention for EPA benefits is to round all results to two significant figures. Here, we report all significant figures so that readers may reproduce the results reported below

Table 4-6: Total Benefits Estimates of Ozone-, NOx- and PM$_{2.5}$-Attributable Premature Mortality and Illness (million 2021$)[a,b,c]

	All Rules					
	Less Stringent Regulatory Option		Proposed Regulatory Option		More Stringent Regulatory Option	
	Discount Rate		Discount Rate		Discount Rate	
	3 Percent	7 Percent	3 Percent	7 Percent	3 Percent	7 Percent
PV	$81 and $730	$55 and $490	$200 and $850	$130 and $570	$85 and $760	$58 and $520
EAV	$6.8 and $61	$6.3 and $54	$17 and $71	$15 and $63	$7.0 and $63	$6.3 and $56
Non-Monetized Benefits						
Health benefits associated with emission reductions of 6,053 tpy of HAP including hexane, benzene, methanol, 1,3-butadiene, and vinyl acetate. Health benefits associated with reduction of 58 tpy of ethylene oxide and 14 tpy of chloroprene. Ecosystem benefits related to the reductions of ozone and nitrogen and sulfur deposition.						

[a] Discounted to 2023

[b] Rounded to 2 significant figures.

[c] Benefits are estimated for Ozone, NOx and PM$_{2.5}$.

Table 4-77: Undiscounted Benefits Estimates of Ozone-, NOx- and $PM_{2.5}$-Attributable Premature Mortality and Illness for the Proposed Option (million 2021$), 2024-2038[a,b]

	3 Percent		7 Percent	
Year				
2024	$16	$67	$14	$60
2025	$16	$67	$14	$60
2026	$16	$67	$14	$60
2027	$16	$67	$14	$60
2028	$17	$74	$15	$66
2029	$17	$74	$15	$66
2030	$17	$74	$15	$66
2031	$17	$74	$15	$66
2032	$17	$74	$15	$66
2033	$18	$81	$17	$73
2034	$18	$81	$17	$73
2035	$18	$81	$17	$73
2036	$18	$81	$17	$73
2037	$18	$81	$17	$73
2038	$19	$88	$18	$79

[a] Rounded to 2 significant figures

[b] Benefits are estimated for Ozone, NOx and $PM_{2.5}$.

4.6 Characterization of Uncertainty in the Monetized Benefits

In any complex analysis using estimated parameters and inputs from a variety of models, there are likely to be many sources of uncertainty. This analysis is no exception. This analysis includes many data sources as inputs, including emission inventories, air quality data from models (with their associated parameters and inputs), population data, population estimates, health effect estimates from epidemiology studies, economic data for monetizing benefits, and assumptions regarding the future state of the world (*i.e.,* regulations, technology, and human behavior). Each of these inputs are uncertain and generate uncertainty in the benefits estimate. When the uncertainties from each stage of the analysis are compounded, even small uncertainties can have large effects on the total quantified benefits. Therefore, the estimates of annual benefits should be viewed as representative of the magnitude of benefits expected, rather than the actual benefits that would occur every year.

4.7 Climate Impacts

We estimate the social benefits of GHG reductions expected to occur as a result of the proposed standards using estimates of the social cost of greenhouse gases (SC-GHG)[21], specifically using the social cost of carbon (SC-CO_2), social cost of methane (SC-CH_4), and social cost of nitrous oxide (SC-N_2O). The SC-GHG is the monetary value of the net harm to society associated with a marginal increase in GHG emissions in a given year, or the benefit of avoiding that increase. In principle, SC-GHG includes the value of all climate change impacts (both negative and positive), including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk and natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The SC-GHG, therefore, reflects the societal value of reducing emissions of the gas in question by one metric ton and is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect GHG emissions. In practice, data and modeling limitations naturally restrain the ability of SC-GHG estimates to include all the important physical, ecological, and economic impacts of climate change, such that the estimates are a partial accounting of climate change impacts and will therefore tend to be underestimates of the marginal benefits of abatement. The EPA and other Federal agencies began regularly incorporating SC-GHG estimates in their benefit-cost analyses conducted under Executive Order (E.O.) 12866[22] since 2008, following a Ninth Circuit Court of Appeals remand of a rule for failing to monetize the benefits of reducing GHG emissions in that rulemaking process.

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[21] Estimates of the social cost of greenhouse gases are gas-specific (*e.g.*, social cost of carbon (SC-CO_2), social cost of methane (SC-CH_4), social cost of nitrous oxide (SC-N_2O)), but collectively they are referenced as the social cost of greenhouse gases (SC-GHG).

[22] Presidents since the 1970s have issued executive orders requiring agencies to conduct analysis of the economic consequences of regulations as part of the rulemaking development process. E.O. 12866, released in 1993 and still in effect today, requires that for all significant regulatory actions, an agency provide an assessment of the potential costs and benefits of the regulatory action, and that this assessment include a quantification of benefits and costs to the extent feasible. Many statutes also require agencies to conduct at least some of the same analyses required under E.O. 12866, such as the Energy Policy and Conservation Act, which mandates the setting of fuel economy regulations. For purposes of this action, monetized climate benefits are presented for purposes of providing a complete benefit-cost analysis under E.O. 12866 and other relevant executive orders. The estimates of change in GHG emissions and the monetized benefits associated with those changes play no part in the record basis for this action.

In 2017, the National Academies of Sciences, Engineering, and Medicine published a report that provides a roadmap for how to update SC-GHG estimates used in Federal analyses going forward to ensure that they reflect advances in the scientific literature (National Academies, 2017). The National Academies' report recommended specific criteria for future SC-GHG updates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process. The research community has made considerable progress in developing new data and methods that help to advance various components of the SC-GHG estimation process in response to the National Academies' recommendations.

In a first-day executive order (E.O. 13990), Protecting Public Health and the Environment and Restoring Science To Tackle the Climate Crisis, President Biden called for a renewed focus on updating estimates of the social cost of greenhouse gases (SC-GHG) to reflect the latest science, noting that "it is essential that agencies capture the full benefits of reducing greenhouse gas emissions as accurately as possible." Important steps have been taken to begin to fulfill this directive of E.O. 13990. In February 2021, the Interagency Working Group on the SC-GHG (IWG) released a technical support document (hereinafter the "February 2021 TSD") that provided a set of IWG recommended SC-GHG estimates while work on a more comprehensive update is underway to reflect recent scientific advances relevant to SC-GHG estimation (IWG, 2021). In addition, as discussed further below, EPA has developed a draft updated SC-GHG methodology within a sensitivity analysis in the regulatory impact analysis of EPA's November 2022 supplemental proposal for oil and gas standards that is currently undergoing external peer review and a public comment process.[23]

The EPA has applied the IWG's recommended interim SC-GHG estimates in the Agency's regulatory benefit-cost analyses published since the release of the February 2021 TSD and is likewise using them in this RIA. We have evaluated the SC-GHG estimates in the February 2021 TSD and have determined that these estimates are appropriate for use in estimating the social benefits of GHG reductions expected to occur as a result of the proposed and alternative standards. These SC-GHG estimates are interim values developed for use in

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[23] See https://www.epa.gov/environmental-economics/scghg

benefit-cost analyses until updated estimates of the impacts of climate change can be developed based on the best available science and economics. After considering the TSD, and the issues and studies discussed therein, EPA finds that these estimates, while likely an underestimate, are the best currently available SC-GHG estimates until revised estimates have been developed reflecting the latest, peer-reviewed science.

The SC-GHG estimates presented in the February 2021 SC-GHG TSD and used in this RIA were developed over many years, using a transparent process, peer-reviewed methodologies, the best science available at the time of that process, and with input from the public. Specifically, in 2009, an interagency working group (IWG) that included the EPA and other executive branch agencies and offices was established to develop estimates relying on the best available science for agencies to use. The IWG published SC-CO_2 estimates in 2010 that were developed from an ensemble of three widely cited integrated assessment models (IAMs) that estimate global climate damages using highly aggregated representations of climate processes and the global economy combined into a single modeling framework. The three IAMs were run using a common set of input assumptions in each model for future population, economic, and CO_2 emissions growth, as well as equilibrium climate sensitivity (ECS)—a measure of the globally averaged temperature response to increased atmospheric CO_2 concentrations. These estimates were updated in 2013 based on new versions of each IAM (Nordhaus (2010), Anthoff (2013a) and (2013b), Hope (2013)).[24] In August 2016,the IWG published estimates of the social cost of methane (SC-CH_4) and nitrous oxide (SC-N_2O) using methodologies that are consistent with the methodology underlying the SC-CO_2 estimates. The modeling approach that extends the IWG SC-CO_2 methodology to non-CO_2 GHGs has undergone multiple stages of peer review. The SC-CH_4 and SC-N_2O estimates were developed by Marten, Kopits, Griffiths, Newbold, and Wolverton (2015) and underwent a standard double-blind peer review process prior to journal publication. These estimates were applied in regulatory impact analyses of EPA proposed rulemakings with CH_4 and N_2O emissions impacts.[25] The EPA

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[24] Dynamic Integrated Climate and Economy (DICE), Climate Framework for Uncertainty, Negotiation, and Distribution (FUND), and Policy Analysis of the Greenhouse Gas Effect (PAGE) 2009

[25] The SC-CH_4 and SC-N_2O estimates were first used in sensitivity analysis for the Proposed Rulemaking for Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles–Phase 2 (U.S. EPA, 2015a).

also sought additional external peer review of technical issues associated with its application to regulatory analysis. Following the completion of the independent external peer review of the application of the Marten et al. (2015) estimates, the EPA began using the estimates in the primary benefit-cost analysis calculations and tables for a number of proposed rulemakings in 2015 (U.S. EPA, 2015b), (U.S. EPA, 2015c). The EPA considered and responded to public comments received for the proposed rulemakings before using the estimates in final regulatory analyses in 2016.[26] In 2015, as part of the response to public comments received to a 2013 solicitation for comments on the SC-CO_2 estimates, the IWG announced a National Academies of Sciences, Engineering, and Medicine review of the SC-CO_2 estimates to offer advice on how to approach future updates to ensure that the estimates continue to reflect the best available science and methodologies. In January 2017, the National Academies released their final report, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, and recommended specific criteria for future updates to the SC-GHG estimates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process (National Academies, 2017). Shortly thereafter, in March 2017, President Trump issued Executive Order 13783, which disbanded the IWG, withdrew the previous TSDs, and directed agencies to ensure SC-GHG estimates used in regulatory analyses are consistent with the guidance contained in OMB's Circular A-4, "including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates" (E.O. 13783, Section 5(c)). Benefit-cost analyses following E.O. 13783 used SC-GHG estimates that attempted to focus on the specific share of climate change damages in the U.S. as captured by the models (which did not reflect many pathways by which climate impacts affect the welfare of U.S. citizens and residents) and were calculated using two discount rates recommended by Circular A-4, 3 percent and 7 percent.[27] All other methodological decisions and model versions used in SC-GHG calculations remained the same as those used by the IWG in 2010 and 2013, respectively.

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[26] See IWG (2016b) for more discussion of the SC-CH_4 and SC-N_2O and the peer review and public comment processes accompanying their development.

[27] The EPA regulatory analyses under E.O. 13783 included sensitivity analyses based on global SC-GHG values and using a lower discount rate of 2.5%. OMB Circular A-4 (OMB, 2003) recognizes that special considerations

On January 20, 2021, President Biden issued Executive Order 13990, which re-established an IWG and directed it to develop an update of the social cost of carbon and other greenhouse gas estimates that reflect the best available science and the recommendations of the National Academies. In February 2021, the IWG recommended the interim use of the most recent SC-GHG estimates developed by the IWG prior to the group being disbanded in 2017, adjusted for inflation (IWG, 2021). As discussed in the February 2021 TSD, the IWG's selection of these interim estimates reflected the immediate need to have SC-GHG estimates available for agencies to use in regulatory benefit-cost analyses and other applications that were developed using a transparent process, peer reviewed methodologies, and the science available at the time of that process.

As noted above, EPA participated in the IWG but has also independently evaluated the interim SC-GHG estimates published in the February 2021 TSD and determined they are appropriate to use here to estimate climate benefits. The EPA and other agencies intend to undertake a fuller update of the SC-GHG estimates that takes into consideration the advice of the National Academies (2017) and other recent scientific literature. The EPA has also evaluated the supporting rationale of the February 2021 TSD, including the studies and methodological issues discussed therein, and concludes that it agrees with the rationale for these estimates presented in the TSD and summarized below.

In particular, the IWG found that the SC-GHG estimates used under E.O. 13783 fail to reflect the full impact of GHG emissions in multiple ways. First, the IWG concluded that those estimates fail to capture many climate impacts that can affect the welfare of U.S. citizens and residents. Examples of affected interests include direct effects on U.S. citizens and assets located abroad, international trade, and tourism, and spillover pathways such as economic and political destabilization and global migration that can lead to adverse impacts on U.S. national security,

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arise when applying discount rates if intergenerational effects are important. In the IWG's 2015 Response to Comments, OMB—as a co-chair of the IWG—made clear that "Circular A-4 is a living document," that "the use of 7 percent is not considered appropriate for intergenerational discounting," and that "[t]here is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself." OMB, as part of the IWG, similarly repeatedly confirmed that "a focus on global SCC estimates in [regulatory impact analyses] is appropriate" (IWG, 2015).

public health, and humanitarian concerns. Those impacts are better captured within global measures of the social cost of greenhouse gases.

In addition, assessing the benefits of U.S. GHG mitigation activities requires consideration of how those actions may affect mitigation activities by other countries, as those international mitigation actions will provide a benefit to U.S. citizens and residents by mitigating climate impacts that affect U.S. citizens and residents. A wide range of scientific and economic experts have emphasized the issue of reciprocity as support for considering global damages of GHG emissions. Using a global estimate of damages in U.S. analyses of regulatory actions allows the U.S. to continue to actively encourage other nations, including emerging major economies, to take significant steps to reduce emissions. The only way to achieve an efficient allocation of resources for emissions reduction on a global basis—and so benefit the U.S. and its citizens—is for all countries to base their policies on global estimates of damages.

As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, the EPA agrees with this assessment and, therefore, in this RIA, the EPA centers attention on a global measure of SC-GHG. This approach is the same as that taken in EPA regulatory analyses over 2009 through 2016. A robust estimate of climate damages to U.S. citizens and residents that accounts for the myriad of ways that global climate change reduces the net welfare of U.S. populations does not currently exist in the literature. As explained in the February 2021 TSD, existing estimates are both incomplete and an underestimate of total damages that accrue to the citizens and residents of the U.S. because they do not fully capture the regional interactions and spillovers discussed above, nor do they include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature, as discussed further below. The EPA, as a member of the IWG, will continue to review developments in the literature, including more robust methodologies for estimating the magnitude of the various damages to U.S. populations from climate impacts and reciprocal international mitigation activities, and explore ways to better inform the public of the full range of carbon impacts.

Second, the IWG concluded that the use of the social rate of return on capital (7 percent under current OMB Circular A-4 guidance) to discount the future benefits of reducing GHG emissions inappropriately underestimates the impacts of climate change for the purposes of estimating the SC-GHG. Consistent with the findings of the National Academies and the economic literature, the IWG continued to conclude that the consumption rate of interest is the theoretically appropriate discount rate in an intergenerational context, and recommended that discount rate uncertainty and relevant aspects of intergenerational ethical considerations be accounted for in selecting future discount rates (IWG (2010), (2013), (2016a), (2016b)).[28] Furthermore, the damage estimates developed for use in the SC-GHG are estimated in consumption-equivalent terms, and so an application of OMB Circular A-4's guidance for regulatory analysis would then use the consumption discount rate to calculate the SC-GHG. EPA agrees with this assessment and will continue to follow developments in the literature pertaining to this issue. EPA also notes that while OMB Circular A-4, as published in 2003, recommends using 3% and 7% discount rates as "default" values, Circular A-4 also reminds agencies that "different regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues and the sensitivity of the benefit and cost estimates to the key assumptions." On discounting, Circular A-4 recognizes that "special ethical considerations arise when comparing benefits and costs across generations," and Circular A-4 acknowledges that analyses may appropriately "discount future costs and consumption benefits…at a lower rate than for intragenerational analysis." In the 2015 Response to Comments on the Social Cost of Carbon for Regulatory Impact Analysis, OMB, EPA, and the other IWG members recognized that "Circular A-4 is a living document" and "the use of 7 percent is not considered appropriate for intergenerational discounting. There is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself." Thus, EPA concludes that a 7% discount rate is not appropriate to apply to value the social cost of greenhouse gases in the analysis presented in this proposal. In this analysis, to calculate the present and annualized values of climate benefits, EPA uses the same discount rate as the rate used to discount the value of damages from future GHG emissions, for internal consistency. That approach to discounting follows the same approach that the February 2021 TSD recommends "to ensure internal consistency—*i.e.*, future damages from

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[28] GHG emissions are stock pollutants, where damages are associated with what has accumulated in the atmosphere over time, and they are long lived such that subsequent damages resulting from emissions today occur over many decades or centuries depending on the specific greenhouse gas under consideration. In calculating the SC-GHG, the stream of future damages to agriculture, human health, and other market and non-market sectors from an additional unit of emissions are estimated in terms of reduced consumption (or consumption equivalents). Then that stream of future damages is discounted to its present value in the year when the additional unit of emissions was released. Given the long time horizon over which the damages are expected to occur, the discount rate has a large influence on the present value of future damages.

climate change using the SC-GHG at 2.5 percent should be discounted to the base year of the analysis using the same 2.5 percent rate." EPA has also consulted the National Academies' 2017 recommendations on how SC-GHG estimates can "be combined in RIAs with other cost and benefits estimates that may use different discount rates." The National Academies reviewed "several options," including "presenting all discount rate combinations of other costs and benefits with [SC-GHG] estimates."

While the IWG works to assess how best to incorporate the latest, peer reviewed science to develop an updated set of SC-GHG estimates, it recommended the interim estimates to be the most recent estimates developed by the IWG prior to the group being disbanded in 2017. The estimates rely on the same models and harmonized inputs and are calculated using a range of discount rates. As explained in the February 2021 TSD, the IWG has concluded that it is appropriate for agencies to revert to the same set of four values drawn from the SC-GHG distributions based on three discount rates as were used in regulatory analyses between 2010 and 2016 and subject to public comment. For each discount rate, the IWG combined the distributions across models and socioeconomic emissions scenarios (applying equal weight to each) and then selected a set of four values for use in agency analyses: an average value resulting from the model runs for each of three discount rates (2.5 percent, 3 percent, and 5 percent), plus a fourth value, selected as the 95th percentile of estimates based on a 3 percent discount rate. The fourth value was included to provide information on potentially higher-than-expected economic impacts from climate change, conditional on the 3 percent estimate of the discount rate. As explained in the February 2021 TSD, this update reflects the immediate need to have an operational SC-GHG that was developed using a transparent process, peer-reviewed methodologies, and the science available at the time of that process. Those estimates were subject to public comment in the context of dozens of proposed rulemakings as well as in a dedicated public comment period in 2013.

Table 4-8, Table 4-9, and Table 4-10 summarize the interim SC-CO_2, SC-CH_4, and SC-N_2O estimates for the years 2024–2038. These estimates are reported in 2020 dollars in the IWG's 2021 TSD but are otherwise identical to those presented in the IWG's 2016 TSD (IWG, 2021). For purposes of capturing uncertainty around the SC-CO_2 estimates in analyses, the February 2021 TSD emphasizes the importance of considering all four of the SC-CO_2 values. The SC-GHG increases over time within the models (*i.e.*, the societal harm from one metric ton emitted in 2030 is higher than the harm caused by one metric ton emitted in 2025) because future emissions produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change, and because GDP is growing over time and many damage categories are modeled as proportional to GDP.

Table 4-8: Interim Social Cost of Carbon Values, 2024-2038 (2021$/Metric Ton CO_2)

Emissions Year	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th Percentile
2024	$17	$58	$85	$173
2025	$18	$59	$86	$176
2026	$18	$60	$88	$180
2027	$19	$61	$89	$184
2028	$19	$62	$90	$187
2029	$20	$63	$92	$191
2030	$20	$64	$93	$194
2031	$21	$66	$95	$198
2032	$21	$67	$96	$202
2033	$22	$68	$97	$206
2034	$23	$69	$99	$210
2035	$23	$70	$100	$214
2036	$24	$71	$102	$218
2037	$24	$73	$103	$222
2038	$25	$74	$105	$226

Note: These SC-CO_2 values are identical to those reported in the 2016 TSD (IWG, 2016a) adjusted to 2021 dollars using the annual GDP Implicit Price Deflator values in the U.S. Bureau of Economic Analysis' (BEA) NIPA Table 1.1.9 (U.S. BEA 2022). This table displays the values rounded to the nearest dollar; the annual unrounded values used in the calculations in this analysis are available on OMB's website: https://www.whitehouse.gov/omb/information-regulatory-affairs/regulatory-matters/#scghgs.

Source: Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (IWG 2021)

Table 4-9: Interim Social Cost of Methane Values, 2024-2038 (2021$ /Metric Ton CH_4)

Emissions Year	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th Percentile
2024	$807	$1,742	$2,265	$4,604
2025	$835	$1,791	$2,323	$4,737
2026	$864	$1,840	$2,381	$4,871
2027	$892	$1,889	$2,439	$5,005
2028	$920	$1,938	$2,496	$5,139
2029	$949	$1,987	$2,554	$5,272
2030	$977	$2,036	$2,612	$5,406
2031	$1,013	$2,093	$2,678	$5,566
2032	$1,049	$2,151	$2,745	$5,726
2033	$1,084	$2,209	$2,811	$5,887
2034	$1,120	$2,266	$2,878	$6,047
2035	$1,156	$2,324	$2,945	$6,207
2036	$1,192	$2,382	$3,011	$6,367
2037	$1,228	$2,439	$3,078	$6,527
2038	$1,263	$2,497	$3,144	$6,687

Note: These SC-CH_4 values are identical to those reported in the 2016 TSD (IWG, 2016a) adjusted to 2021 dollars using the annual GDP Implicit Price Deflator values in the U.S. Bureau of Economic Analysis' (BEA) NIPA Table 1.1.9 (U.S. BEA 2022). This table displays the values rounded to the nearest dollar; the annual unrounded values used in the calculations in this analysis are available on OMB's website: https://www.whitehouse.gov/omb/information-regulatory-affairs/regulatory-matters/#scghgs.
Source: Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (IWG 2021)

Table 4-10: Interim Social Cost of Nitrous Oxide Values, 2024-2038 (2021$ /Metric Ton N_2O)

Emissions Year	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th Percentile
2024	$6,861	$20,991	$30,578	$55,293
2025	$7,071	$21,446	$31,157	$56,550
2026	$7,282	$21,901	$31,737	$57,808
2027	$7,492	$22,357	$32,317	$59,066
2028	$7,702	$22,812	$32,897	$60,324
2029	$7,913	$23,267	$33,477	$61,582
2030	$8,123	$23,722	$34,057	$62,840
2031	$8,381	$24,235	$34,693	$64,256
2032	$8,639	$24,747	$35,330	$65,671
2033	$8,897	$25,259	$35,967	$67,087
2034	$9,155	$25,772	$36,604	$68,502
2035	$9,413	$26,284	$37,241	$69,918
2036	$9,671	$26,797	$37,877	$71,333
2037	$9,929	$27,309	$38,514	$72,749
2038	$10,187	$27,821	$39,151	$74,165

Note: These SC-N_2O values are identical to those reported in the 2016 TSD (IWG, 2016a) adjusted to 2021 dollars using the annual GDP Implicit Price Deflator values in the U.S. Bureau of Economic Analysis' (BEA) NIPA Table 1.1.9 (U.S. BEA 2022). This table displays the values rounded to the nearest dollar; the annual unrounded values used in the calculations in this analysis are available on OMB's website: https://www.whitehouse.gov/omb/information-regulatory-affairs/regulatory-matters/#scghgs.
Source: Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (IWG 2021)

There are a number of limitations and uncertainties associated with the SC-GHG estimates presented in Table 4-8, Table 4-9, and Table 4-10. Some uncertainties are captured within the analysis, while other areas of uncertainty have not yet been quantified in a way that can be modeled. Figure 4-1, Figure 4-2, and Figure 4-3 present the quantified sources of uncertainty in the form of frequency distributions for the SC-CO_2, SC-CH_4, and SC-N_2O estimates for emissions in 2030 (in 2021$). The distribution of the SC-CO_2 estimate reflects uncertainty in key model parameters such as the equilibrium climate sensitivity, as well as uncertainty in other parameters set by the original model developers. To highlight the difference between the impact of the discount rate and other quantified sources of uncertainty, the bars below the frequency distributions provide a symmetric representation of quantified variability in the SC-CO_2 estimates for each discount rate. As illustrated by the figure, the assumed discount rate plays a critical role in the ultimate estimate of the SC-CO_2. This is because CO_2 emissions today continue to impact society far out into the future, so with a higher discount rate, costs that accrue to future generations are weighted less, resulting in a lower estimate. As discussed in the February 2021 TSD, there are other sources of uncertainty that have not yet been quantified and are thus not reflected in these estimates.

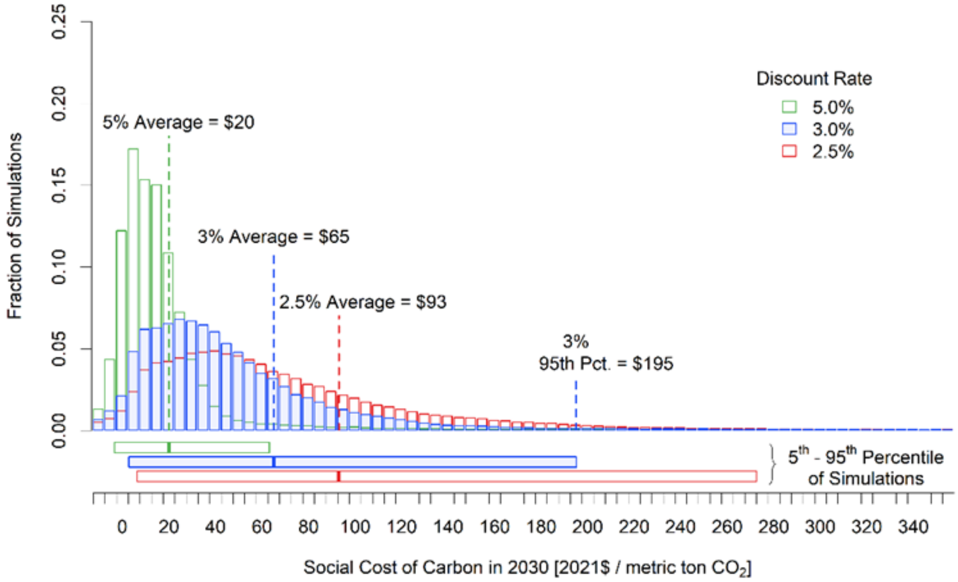

Figure 4-1: Frequency Distribution of SC-CO$_2$ Estimates for 2030[29]

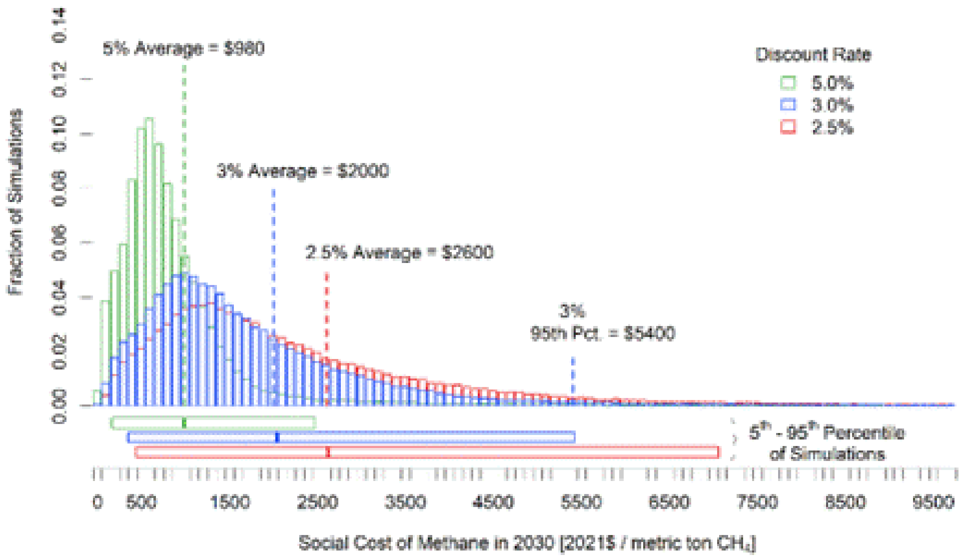

Figure 4-2: Frequency Distribution of SC-CH$_4$ Estimates for 2030[30]

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[29] Although the distributions and numbers are based on the full set of model results (150,000 estimates for each discount rate and gas), for display purposes the horizontal axis is truncated with 0.47 to 0.89 percent of the estimates falling below the lowest bin displayed and 0.30 to 3.7 percent of the estimates falling above the highest bin displayed, depending on the discount rate and GHG.

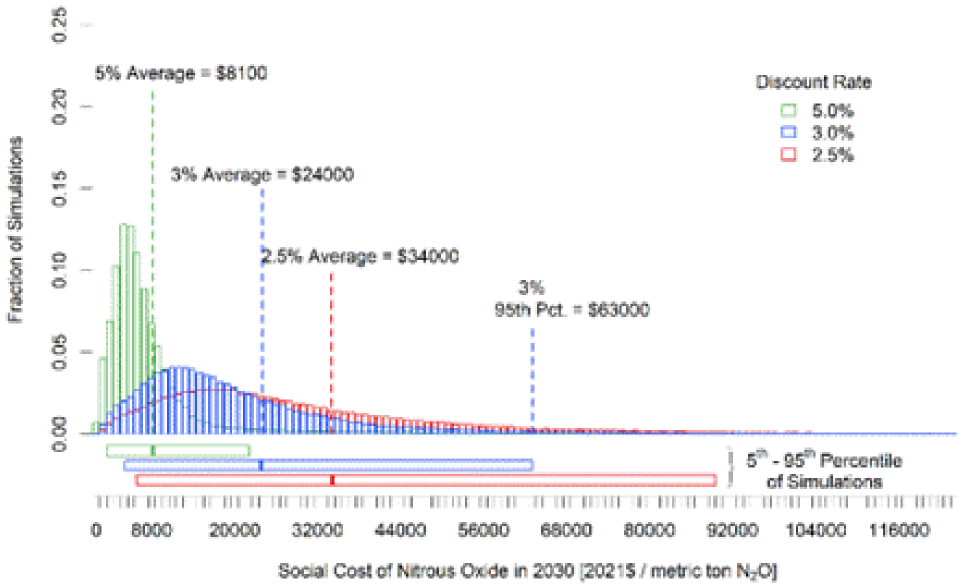

Figure 4-3: Frequency Distribution of SC-N_2O Estimates for 2030[31]

The interim SC-GHG estimates presented in Table 4-8, Table 4-9, and Table 4-10 have a number of limitations. First, the current scientific and economic understanding of discounting approaches suggests discount rates appropriate for intergenerational analysis in the context of climate change are likely to be less than 3 percent, near 2 percent or lower (IWG, 2021). Second, the IAMs used to produce these interim estimates do not include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature and the science underlying their "damage functions" – *i.e.*, the core parts of the IAMs that map global mean temperature changes and other physical impacts of climate change into economic (both market and nonmarket) damages – lags behind the most recent research. For example, limitations include the incomplete treatment of catastrophic and non-catastrophic impacts in the integrated assessment models, their incomplete treatment of adaptation and technological change, the incomplete way in which inter-regional and intersectoral linkages are modeled, uncertainty in the extrapolation of damages to high temperatures, and inadequate representation

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[30] Although the distributions and numbers are based on the full set of model results (150,000 estimates for each discount rate and gas), for display purposes the horizontal axis is truncated with 0.018 to 0.106 percent of the estimates falling below the lowest bin displayed and 0.42 to 2.88 percent of the estimates falling above the highest bin displayed, depending on the discount rate and GHG.

[31] Although the distributions and numbers are based on the full set of model results (150,000 estimates for each discount rate and gas), for display purposes the horizontal axis is truncated with 0.036 to 0.098 percent of the estimates falling below the lowest bin displayed and 0.072 to 2.9 percent of the estimates falling above the highest bin displayed, depending on the discount rate and GHG.

of the relationship between the discount rate and uncertainty in economic growth over long time horizons. Likewise, the socioeconomic and emissions scenarios used as inputs to the models do not reflect new information from the last decade of scenario generation or the full range of projections.

The modeling limitations do not all work in the same direction in terms of their influence on the SC-GHG estimates. However, as discussed in the February 2021 TSD, the IWG has recommended that, taken together, the limitations suggest that the SC-CO_2 estimates used in this rule likely underestimate the damages from GHG emissions. EPA concurs that the values used in this RIA conservatively underestimate the rule's climate benefits. In particular, the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, which was the most current IPCC assessment available at the time when the IWG decision over the ECS input was made, concluded that SC-GHG estimates "very likely…underestimate the damage costs" due to omitted impacts (IPCC, 2007). Since then, the peer-reviewed literature has continued to support this conclusion, as noted in the IPCC's Fifth Assessment report and other recent scientific assessments (IPCC, 2014), (IPCC, 2018), (IPCC, 2019a), (IPCC, 2019b), (USGCRP, 2016), (USGCRP, 2018), (National Academies, 2016b), (National Academies, 2019). These assessments confirm and strengthen the science, updating projections of future climate change and documenting and attributing ongoing changes. For example, sea level rise projections from the IPCC's Fourth Assessment report ranged from 18 to 59 centimeters by the 2090s relative to 1980-1999, while excluding any dynamic changes in ice sheets due to the limited understanding of those processes at the time. A decade later, the Fourth National Climate Assessment projected a substantially larger sea level rise of 30 to 130 centimeters by the end of the century relative to 2000, while not ruling out even more extreme outcomes. EPA has reviewed and considered the limitations of the models used to estimate the interim SC-GHG estimates and concurs with the February 2021 SC-GHG TSD's assessment that, taken together, the limitations suggest that the interim SC-GHG estimates likely underestimate the damages from GHG emissions.

The February 2021 TSD briefly previews some of the recent advances in the scientific and economic literature that the IWG is actively following and that could provide guidance on, or methodologies for, addressing some of the limitations with the interim SC-GHG estimates. The IWG is currently working on a comprehensive update of the SC-GHG estimates taking into consideration recommendations from the National Academies of Sciences, Engineering and

Medicine, recent scientific literature, public comments received on the February 2021 TSD and other input from experts and diverse stakeholder groups (National Academies, 2017). While that process continues, the EPA is continuously reviewing developments in the scientific literature on the SC-GHG, including more robust methodologies for estimating damages from emissions, and looking for opportunities to further improve SC-GHG estimation going forward. Most recently, the EPA presented a draft set of updated SC-GHG estimates within a sensitivity analysis in the regulatory impact analysis of the EPA's November 2022 supplemental proposal for oil and gas standards that that aims to incorporate recent advances in the climate science and economics literature. Specifically, the draft updated methodology incorporates new literature and research consistent with the National Academies near-term recommendations on socioeconomic and emissions inputs, climate modeling components, discounting approaches, and treatment of uncertainty, and an enhanced representation of how physical impacts of climate change translate to economic damages in the modeling framework based on the best and readily adaptable damage functions available in the peer reviewed literature. The EPA solicited public comment on the sensitivity analysis and the accompanying draft technical report, which explains the methodology underlying the new set of estimates, in the docket for the proposed Oil and Gas rule. The EPA is also conducting an external peer review of this technical report. More information about this process and public comment opportunities is available on EPA's website.[32] EPA's draft technical report will be among the many technical inputs available to the IWG as it continues its work.

Table 4-11 show the estimated monetary value of the estimated changes in CO_2, CH_4, N_2O, and total GHG emissions expected to occur over 2024 through 2038 for this proposal. The EPA estimated the dollar value of the GHG-related effects for each analysis year between 2024 and 2038 by applying the SC-GHG estimates presented in Table 4-8, Table 4-9, and Table 4-10 to the estimated changes in GHG emissions in the corresponding year as shown in Chapter 3. The EPA then calculated the present value (PV) and equivalent annualized value (EAV) of

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[32] See https://www.epa.gov/environmental-economics/scghg

benefits from the perspective of 2023 by discounting each year-specific value to the year 2023 using the same discount rate used to calculate the SC-GHG.[33]

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[33] According to OMB's Circular A-4 (OMB, 2003), an "analysis should focus on benefits and costs that accrue to citizens and residents of the United States", and international effects should be reported, but separately. Circular A-4 also reminds analysts that "[d]ifferent regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues." To correctly assess the total climate damages to U.S. citizens and residents, an analysis should account for all the ways climate impacts affect the welfare of U.S. citizens and residents, including how U.S. GHG mitigation activities affect mitigation activities by other countries, and spillover effects from climate action elsewhere. The SC-GHG estimates used in regulatory analysis under revoked EO 13783 were a limited approximation of some of the U.S. specific climate damages from GHG emissions. These estimates range from \$8 per metric ton CO_2, \$222 per metric ton CH_4, and \$2,594 per ton N_2O (2021 dollars) using a 3 percent discount rate for emissions occurring in 2024 to \$10 per metric ton CO_2, \$315 per metric ton CH_4, and \$3,408 per ton N_2O using a 3 percent discount rate for emissions occurring in 2038. Applying the same estimate (based on a 3% discount rate) to the GHG emissions reduction expected under this proposed rule would yield benefits from climate impacts within U.S borders of -\$5.8 million in 2024, increasing to -\$7.4 million in 2038 for CO_2, \$5 million in 2024, increasing to \$7.2 million in 2038 for CH_4, and -\$0.018 million in 2024, increasing to -\$0.023 million in 2038 for N_2O. However, as discussed at length in the IWG's February 2021 SC-GHG TSD, these estimates are an underestimate of the benefits of GHG mitigation accruing to U.S. citizens and residents, as well as being subject to a considerable degree of uncertainty due to the manner in which they are derived. In particular, as discussed in this analysis, EPA concurs with the assessment in the February 2021 SC-GHG TSD that the estimates developed under revoked E.O. 13783 did not capture significant regional interactions, spillovers, and other effects and so are incomplete underestimates. As the U.S. Government Accountability Office (GAO) concluded in a June 2020 report examining the SC-GHG estimates developed under E.O. 13783, the models "were not premised or calibrated to provide estimates of the social cost of carbon based on domestic damages" p.29 (U.S. GAO, 2020). Further, the report noted that the National Academies found that country-specific social costs of carbon estimates were "limited by existing methodologies, which focus primarily on global estimates and do not model all relevant interactions among regions" p.26 (U.S. GAO, 2020). It is also important to note that the SC-GHG estimates developed under E.O. 13783 were never peer reviewed, and when their use in a specific regulatory action was challenged, the U.S. District Court for the Northern District of California determined that use of those values had been "soundly rejected by economists as improper and unsupported by science," and that the values themselves omitted key damages to U.S. citizens and residents including to supply chains, U.S. assets and companies, and geopolitical security. The Court found that by omitting such impacts, those estimates "fail[ed] to consider…important aspect[s] of the problem" and departed from the "best science available" as reflected in the global estimates. California v. Bernhardt, 472 F. Supp. 3d 573, 613-14 (N.D. Cal. 2020). The EPA continues to center attention in this analysis on the global measures of the SC-GHG as the appropriate estimates given the flaws in the U.S. specific estimates, and as necessary for all countries to use to achieve an efficient allocation of resources for emissions reduction on a global basis, and so benefit the U.S. and its citizens.

Table 4-11: Monetized Benefits of Estimated CO_2, CH_4, N_2O Changes of the Proposed HON Amendments, P&R I and P&R II NESHAP and Subpart VVb, IIIa, NNNa, and RRRa NSPS Amendments, 2024-2038, (million 2021$)

	SC-CO_2 (Millions of 2021$)				SC-CH_4 (Millions of 2021$)				SC-N_2O (Millions of 2021$)			
	Discount rate and statistic				Discount rate and statistic				Discount rate and statistic			
Year	5% Average	3% Average	2.5% Average	3% 95th Percentile	5% Average	3% Average	2.5% Average	3% 95th Percentile	5% Average	3% Average	2.5% Average	3% 95th Percentile
2024	$(13)	$(43)	$(63)	$(128)	$19	$40	$52	$106	$(0.05)	$(0.14)	$(0.21)	$(0.38)
2025	$(13)	$(44)	$(64)	$(131)	$19	$41	$53	$109	$(0.05)	$(0.15)	$(0.21)	$(0.39)
2026	$(13)	$(44)	$(65)	$(133)	$20	$42	$55	$112	$(0.05)	$(0.15)	$(0.22)	$(0.40)
2027	$(14)	$(45)	$(66)	$(136)	$20	$43	$56	$115	$(0.05)	$(0.15)	$(0.22)	$(0.41)
2028	$(14)	$(46)	$(67)	$(139)	$21	$44	$57	$118	$(0.05)	$(0.16)	$(0.23)	$(0.41)
2029	$(15)	$(47)	$(68)	$(141)	$22	$46	$59	$121	$(0.05)	$(0.16)	$(0.23)	$(0.42)
2030	$(15)	$(48)	$(69)	$(144)	$22	$47	$60	$124	$(0.06)	$(0.16)	$(0.23)	$(0.43)
2031	$(15)	$(49)	$(70)	$(147)	$23	$48	$61	$128	$(0.06)	$(0.17)	$(0.24)	$(0.44)
2032	$(16)	$(49)	$(71)	$(150)	$24	$49	$63	$131	$(0.06)	$(0.17)	$(0.24)	$(0.45)
2033	$(16)	$(50)	$(72)	$(153)	$25	$51	$65	$135	$(0.06)	$(0.17)	$(0.25)	$(0.46)
2034	$(17)	$(51)	$(73)	$(156)	$26	$52	$66	$139	$(0.06)	$(0.18)	$(0.25)	$(0.47)
2035	$(17)	$(52)	$(74)	$(159)	$27	$53	$68	$142	$(0.06)	$(0.18)	$(0.26)	$(0.48)
2036	$(18)	$(53)	$(75)	$(162)	$27	$55	$69	$146	$(0.07)	$(0.18)	$(0.26)	$(0.49)
2037	$(18)	$(54)	$(76)	$(165)	$28	$56	$71	$150	$(0.07)	$(0.19)	$(0.26)	$(0.50)
2038	$(19)	$(55)	$(77)	$(168)	$29	$57	$72	$153	$(0.07)	$(0.19)	$(0.27)	$(0.51)
NPV	($149)	($558)	($842)	($1,690)	$225	$552	$738	$1,469	($1)	($2)	($3)	($5)
EAV	$(15)	$(48)	$(70)	$(146)	$23	$48	$61	$127	($0.1)	($0.2)	($0.2)	($0.4)

4.8 Total Monetized Benefits

Table 4-12 through Table 4- present a summary of monetized benefits for the proposed amendments to rules included in this rulemaking, both individually and cumulatively. Net benefits in each table are calculated as the sum of health benefits and climate benefits (including climate disbenefits). Benefits related to both short- and long-term exposure of ozone are estimated. Tables presenting benefits list both estimates, with short-term exposure benefits listed first. A complete presentation of benefits relative to costs appears in Chapter 6 of this RIA. We note, as we mentioned in Chapter 1, that there are minimal monetized benefits for the proposed P&R II amendments, and hence there is no table of benefits for this proposed rule below. In addition, the benefits for the Subpart VVb and IIIa, NNNa, and RRRa NSPS proposals are the same for the less and more stringent options, and thus those estimates are already presented earlier in this chapter. Hence, there is no table of benefits for each of these proposed rules below.

Table 4-12: Summary of Monetized Benefits PV/EAV for the Proposed HON Amendments, 2024-2038, (million 2021$), Discounted to 2023

	Proposal		Less Stringent Alternative		More Stringent Alternative	
3%	**PV**	**EAV**	**PV**	**EAV**	**PV**	**EAV**
Monetized Health Benefits	$78 and $690	$6.5 and $58	$52 and $427	$4.4 and $36	$228 and $1,900	$19 and $160
Climate Disbenefits	$(25.4)	$(2.1)	$(25.4)	$(2.1)	$(25.4)	$(2.1)
Net Benefits	$103 and $715	$8.6 and $60	$77 and $452	$6.5 and $38	$253 and $1,925	$21 and $162
7%						
Monetized Health Benefits	$111 and $900	$12 and $99	$32 and $256	$3.5 and $28	$137 and $1,100	$15 and $120
Climate Disbenefits (3%)	$(25.4)	$(2.1)	$(25.4)	$(2.1)	$(25.4)	$(2.1)
Net Benefits	$136 and $925	$14.1 and $101	$57.4 and $281	$5.6 and $30	$162 and $1,125	$17 and $122

Note: Monetized air-quality related health benefits include ozone related health benefits associated with reductions in VOC emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent. The two benefits estimates are separated by the word “and” to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates. Benefits from HAP reductions and VOC reductions outside of the ozone season remain unmonetized and are thus not reflected in the table. The unmonetized effects also include disbenefits resulting from a secondary increase in CO emissions. Monetized climate benefits and disbenefits are based on changes (increases) in CO_2 and N_2O emissions and decreases in CH_4 emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC-GHG) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the benefits and disbenefits associated with the model average SC-GHG at a 3 percent discount rate, but the Agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits and disbenefits calculated using all four SC-GHG estimates; please see Table 4-11 for the full range of SC-GHG estimates. As discussed in Chapter 4, a consideration of climate benefits and disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts.

The costs included in estimates of net benefits in this table are 2024 annual estimates. Parentheses around a number denotes a negative value. Negative climate disbenefits is a positive value. Rows may not appear to add correctly due to rounding.

Table 4-13: Summary of Monetized Benefits PV/EAV for the Proposed P&R I Amendments, 2024-2038, (million 2021$), Discounted to 2023

	Proposal		**Less Stringent Alternative**		**More Stringent Alternative**	
3%	**PV**	**EAV**	**PV**	**EAV**	**PV**	**EAV**
Monetized Health Benefits	$2.6 and $23	$0.22 and $1.9	$2.6 and $23	$0.22 and $1.9	$4 and $36	$0.34 and $3.0
Climate Disbenefits	$40.5	$3.4	$40.5	$3.4	$40.5	$3.4
Net Benefits	$(38) and $(18)	$(3) and $(1)	$(38) and $(18)	$(3) and $(1)	$(36) and $(4.5)	$(2.7) and $(0.4)
7%						
Monetized Health Benefits	$1.8 and $16	$0.19 and $1.7	$1.8 and $16	$0.19 and $1.7	$2.7 and $24	$0.3 and $2.7
Climate Disbenefits (3%)	$40.5	$3.4	$40.5	$3.4	$40.5	$3.4
Net Benefits	$(39) and $(25)	$(3.2) and $(1.7)	$(39) and $(25)	$(3.2) and $(1.7)	$(37) and $(17)	$(3.1) and $(0.7)

Note: Monetized benefits include ozone related health benefits associated with reductions in VOC emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates. Benefits from HAP reductions and VOC reductions outside of the ozone season remain unmonetized and are thus not reflected in the table. The unmonetized effects also include disbenefits resulting from a secondary increase in CO emissions. Monetized climate benefits and disbenefits are based on changes (increases) in CO_2 and N_2O emissions and decreases in CH_4 emissions are calculated using four different estimates of the social cost of carbon (SC-GHG) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the benefits and disbenefits associated with the model average SC-GHG at a 3 percent discount rate, but the Agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits and disbenefits calculated using all four SC-GHG estimates; please see Table 4-11 for the full range of SC-GHG estimates. As discussed in Chapter 4, a consideration of climate benefits and disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. The costs included in estimates of net benefits in this table are 2024 annual estimates. Parentheses around a number denotes a negative value. Negative climate disbenefits are a positive value. Rows may not appear to add correctly due to rounding.

Table 4-14: Summary of Monetized Benefits PV/EAV for the Cumulative Impact of the Proposed HON Amendments, P&R I and P&R II NESHAP and Subpart VVb, IIIa, NNNa, and RRRa NSPS Amendments, 2024-2038, (million 2021$), Discounted to 2023

	Proposal		Less Stringent Alternative		More Stringent Alternative	
3%	PV	EAV	PV	EAV	PV	EAV
Health Benefits	$84 and $730	$7.0 and $63	$81 and $729	$7.0 and $63	$85 and $760	$7.0 and $63
Climate Disbenefits	$8.2	$0.7	$8.2	$0.7	$8.2	$0.7
Net Benefits	$76 and $722	$6.3 and $62	$73 and $721	$2.1 and $34	$77 and $758	$6.3 and $57
7%						
Health Benefits	$56 and $490	$6.1 and $54	$55 and $490	$6.3 and $56	$58 and $520	$6.3 and $56
Climate Disbenefits (3%)	$8.2	$0.7	$8.2	$0.7	$8.2	$0.7
Net Benefits	$48 and $482	$5.4 and $53	$47 and $482	$5.6 and $55	$50 and $512	$5.6 and $55
Non-Monetized Benefits						
Health benefits associated with emission reductions of 6,053 tpy of HAP including hexane, benzene, methanol, 1,3-butadiene and vinyl acetate.						
Health benefits associated with reduction of 58 tpy of ethylene oxide and 14 tpy of chloroprene.						
Ecosystem benefits related to the reductions of ozone and nitrogen and sulfur deposition.						

Note: Monetized benefits include ozone related health benefits associated with reductions in VOC emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates. Benefits from HAP reductions and VOC reductions outside of the ozone season remain unmonetized and are thus not reflected in the table. The unmonetized effects also include disbenefits resulting from a secondary increase in CO emissions. Monetized climate benefits and disbenefits are based on changes (increases) in CO_2 and N_2O emissions and decreases in CH_4 emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC-GHG) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the benefits and disbenefits (including net benefits) associated with the average SC-GHG at a 3 percent discount rate, but the Agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits and disbenefits calculated using all four SC-GHG estimates; please see Table 4-11 for the full range of SC-GHG estimates. As discussed in Chapter 4, a consideration of climate benefits and disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. The costs included in estimates of net benefits in this table are 2024 annual estimates. A number with parentheses around it is a negative value. Negative climate disbenefits are a positive value. Rows may not appear to add correctly due to rounding.

5 ECONOMIC IMPACT ANALYSIS

5.1 Introduction

The proposed amendments to the NESHAP for the HON constitute a significant action according to Executive Order 12866. As discussed in the previous section, the emissions reductions projected under the action are projected to produce substantial VOC health benefits. At the same time, these proposed HON amendments are projected to result in environmental control expenditures by the synthetic organic chemical manufacturing sector to comply with the rule. The proposed amendments to the NESHAPs for P&R Group I and II, and their respective NSPS subparts (III, NNN, RRR, & VV) are not projected to be significant, but they also are expected to result in VOC health benefits and increased environmental control expenditures.

Economic impact analyses focus on changes in market prices and output levels. If changes in market prices and output levels in the primary markets are significant enough, impacts on other markets may also be examined. Both the magnitude of costs needed to comply with a proposed rule and the distribution of these costs among affected facilities can have a role in determining how the market will change in response to a rule. This chapter analyzes three sets of economic impact, small entity, and distributional analyses for each individual rule included in this proposal action directed toward complementing the benefit-cost analysis and includes a partial equilibrium analysis of market impacts of three sets of NESHAP amendments from this rule package, analysis of impacts to potentially affected small entities, and employment impacts.

5.2 Economic Impact Analysis

This section summarizes the economic analysis of environmental control costs for the synthetic organic chemicals manufacturing industries (SOCMI). This analysis models the impact of two sets of control costs for three different proposed NESHAP amendments for the HON and P&R Group I and II, specifically. The analysis does not include economic impacts calculated for four proposed New Source Performance Standards (NSPS) – subparts III, NNN, RRR, and VV – that are part of the same rulemaking in which the three different NESHAP are also included.

This section outlines the data and sources used to calibrate and parameterize a simplified partial equilibrium model representing elastic domestic and foreign sources of supply and a single domestic consumer with elastic preferences. The model uses different cost shocks, including domestic compliance costs, foreign inflation, and combinations.

Economic analysis was conducted for seven synthetic organic chemicals in the SOCMI list. These chemicals were selected for their relative market size and the availability of data to conduct the economic analysis. The seven chemicals for which market analysis was conducted are butadiene, styrene, acrylonitrile, acetone, ethylene dichloride, ethylene glycol, and ethylene oxide.

5.3 Description of Approach/Model/Framework

5.3.1.1 Data Limitations

There were several limitations to data inputs for the economic modeling, including the availability of production data, the allocation of the control costs from facilities to individual chemical markets, and the ability to find specific market dynamics (elasticity) data. For production data, the primary source for most of the chemicals in this analysis included the American Fuel & Petrochemical Manufacturers (AFPM) Petrochemical Statistics dataset published in the first quarter of 2022.

For cost data, control costs were calculated by facility, but little detail was initially available on facility-level production, such as chemical or quantities produced. To allocate the control costs to specific chemicals, data was sourced from Securities and Exchange Commission (SEC) filings, company websites, and specific industry reports to identify chemicals produced at each facility to support the method for cost allocation from facilities to individual chemical markets for the partial equilibrium analysis.

For market supply and demand elasticities, no sources of previous SOCMI modeling were found, so elasticities were assigned to chemicals based on markets associated with end use products for the chemicals (such as different types of plastics or PVC piping).

These limitations are discussed more in detail in the following two subsections.

5.3.1.2 Benchmark Data

There are approximately 400 synthetic organic chemicals, nearly all of which are contained within a single 6-digit North American Industry Classification System (NAICS) code (325199). A detailed description of the approximately 25 largest SOCMI markets is contained in the SOCMI Industry Profile prepared for this proposed action.[34] The main limitation of collecting data for the industry profile was a lack of domestic production for each of the synthetic organic chemicals.

Trade data do, however, provide more granular information on products via harmonized system (HS) commodity codes. For the economic analysis, we selected seven of the largest SOCMI sectors, drawing domestic production quantities from the AFPM Petrochemical Statistics dataset, prices from Intratec commodities data (Intratec, 2023), and trade quantities from the United Nations "Comtrade" dataset (United Nations, 2022). Table 5-1 summarizes the physical quantities and prices for each of the seven chemicals included in the analysis.

Table 5-1: Prices, Production, and Trade Quantities for the Seven Synthetic Organic Chemical Commodities Selected (in Metric Tons)

Chemical	U.S. Production (tonnes)	Exports (tonnes)	Imports (tonnes)	Price ($/tonne)
Butadiene	1,218,232	46,261	391,496	1,220
Styrene	3,659,415	1,099,780	211,776	1,841
Acrylonitrile	848,390	529,330	9,003	1,040
Acetone	1,514,800	42,229	84,459	1,839
Ethylene dichloride	9,731,200	727,454	475	723
Ethylene glycol	1,578,142	1,269,166	236,920	1,220
Ethylene oxide	2,400,027	928	5	1,486

5.3.1.3 Control Data

Control cost data are available for 225 facilities subject to HON or P&R I, not including the value of product recovery, which occurs in the HON and P&R I cost analyses due to detection and repair of equipment leaks. Inclusion of the value of product recovery would lead to double counting of impacts from a social welfare perspective. More information on how product recovery is estimated and monetized can be found in Section 3.3 of this RIA. The control cost data did not include the production processes or a detailed accounting of chemicals produced at the facilities. To develop a method to allocate the control costs to specific chemicals, we reviewed annual SEC filings (for most companies the 2021 10-k Report) and facility websites for all facilities to identify the chemicals produced at the facility. We found general information

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[34] RTI International. SOCMI Industry Profile. Prepared for the U.S. EPA. July 2022.

about the types of chemicals produced at 116 (51 percent) of those facilities and more detailed production data by chemical names for 79 (36 percent) of the facilities.

For the 79 facilities with the best (*i.e.,* most complete) chemical production data, we used this information to identify which of the facilities were producing butadiene, styrene, acrylonitrile, and acetone. We allocated the control costs to these chemicals at the 79 facilities by equally distributing the control costs based on the total number of chemicals identified in production at that facility. The control costs for each chemical were then scaled up to the entire population based on the percentage of total control costs represented in the population of 79 facilities with specific chemical data.

For ethylene dichloride, ethylene glycol, and ethylene oxide, we reviewed publicly available reports to identify facilities that produced each specific chemical and then allocated a portion of the facility's HON costs to their production. The P&R costs apply only to polymers and resin products, so only HON costs were relevant for these three chemicals. For ethylene dichloride, a technical report on the conditions of use for ethylene dichloride listed the 15 facilities producing ethylene dichloride in the United States in 2018 (Material Research L3C, 2019). We allocated half of the HON control costs at each of these facilities to ethylene dichloride because most of these facilities are PVC production facilities, and ethylene dichloride is one of the two major chemical inputs, but there was not enough data to determine how much of the HON costs would be applied to the other chemicals produced.

The ethylene oxide facilities were identified from a Bloomberg Law article (Saiyid, 2019) that listed the top 16 sources of ethylene oxide emissions, 10 of which were production facilities and the other 6 were medical sterilization facilities. The American Chemistry Society (2023) stated that at the end of 2018 the United States had 15 ethylene oxide facilities. The ethylene glycol facilities were identified from a toxicology profile from the Department of Health and Human Services (DHHS) (2010). The list of ethylene glycol facilities was from 2008, so it may not include all current production facilities. The DHHS report noted that nine ethylene oxide production facilities were included in the HON control cost data, six of which also produced ethylene oxide. These facilities did not generally provide detailed production data by chemical; for ethylene glycol and ethylene oxide, half of the HON costs for each facility were allocated to each chemical. Because only 10 of the 15 ethylene glycol production facilities were identified, the HON costs were multiplied by 1.5 to represent the entire population of facilities. Table 5-2 details the control costs for each chemical used in the model. Three of the seven chemicals are found to have total control costs of more than one percent of total domestic production value, though none reach two percent or higher.

Table 5-2: Control Costs Attributed to Each Chemical Modeled (2021$)

Chemical	HON Control Cost (USD/yr)	P&R Control Costs (USD/yr)	Total Control Costs (USD/yr)	Domestic Production Value (USD/yr)	Total Control Cost % of Domestic Value
Acrylonitrile	$13,370,931	$886,272	$14,257,202	$880,400,521	1.619%
Acetone	$4,816,333	$1,965,581	$6,781,915	$2,779,501,547	0.244%
Butadiene	$4,921,906	$3,895,051	$8,816,958	$1,483,128,462	0.594%
Ethylene dichloride	$8,684,650	$0	$8,684,650	$7,022,564,654	0.124%
Ethylene glycol	$22,905,950	$0	$22,905,950	$1,633,103,944	1.403%
Ethylene oxide	$36,441,600	$0	$36,441,600	$3,559,565,671	1.024%
Styrene	$11,487,402	$4,794,858	$16,282,260	$6,722,358,387	0.242%
All 255 facilities	$163,572,000	$16,514,700	$180,086,700		

5.3.1.4 Synthetic Organic Chemicals Manufacturing Industries (SOCMI) Model

For the analysis, EPA developed a simplified partial equilibrium model that can be calibrated to the benchmark data above. The model represents elastic domestic and foreign production and consumption (four elasticities) and a domestic consumer foreign-domestic substitution elasticity (one elasticity). Elasticity estimates are scarce for the specific chemicals. We identified several key elasticity values to populate our five elasticity parameters. For supply elasticities, we used a value of 0.54 from Chambers and Lichtenberg (1994) econometric estimation of long-run fertilizer supply for all chemicals except acetone. For acetone, we used a supply elasticity value of 0 because it is a byproduct of the production of phenol, a much higher value product.

For demand elasticities, we used values associated with a predominant end use industry for the product, if possible. For styrene, butadiene, ethylene glycol, ethylene dichloride, and ethylene oxide, we used a value of −0.38 from Trangadisaikul's (2011) econometric estimation of global tire demand, a proxy market for rubber production.

Ethylene oxide is most commonly used for sterilizing medical equipment, and ethylene glycol and ethylene dichloride are more commonly used in plastic production, but demand elasticity data for those markets were not found in our research, so we used the secondary market of a rubber production input. For acrylonitrile and acetone, we used a value of −1.04 from Martinez's (2012) estimation of demand elasticity for human-made fabrics in the textile industry because textile fiber production is a common use for those two chemicals. Last, we took a foreign-domestic consumer demand substitution elasticity estimate of −2.4 from Ahmad and Riker (2019) in order to account for substitution in consumer demand between domestic and foreign production of these chemicals. Our current estimates are summarized in Table 5-3.

Table 5-3: Elasticity Parameter Values and Sources

Elasticity	Symbol	Value	Source
Supply [domestic (y), imports (m)]	$\sigma_y = \sigma_m$	0.54	Chambers and Lichtenberg (1994)
Demand [domestic (d), foreign (f)]	$\sigma_{dD} = \sigma_{fD}$	-0.38	Trangadisaikul's (2011)
	$\sigma_{dD} = \sigma_{fD}$	-1.04	Martinez (2012)
Consumer substitution	σ_{df}	-2.4	Ahmad and Riker (2019)

The model is a modified version of that specified in Riker and Schreiber (Riker, 2019) in combination with the calibrated share form of the constant elasticity of substitution (CES) function detailed in Rutherford (2002). However, the original distinction between different import sources is removed since our model is only intended to cover domestic compliance cost shocks. Elastic domestic and foreign production is specified as:

$$Y = \bar{Y}\left(\frac{P_y}{\bar{P}_y}\right)^{\sigma_y} \tag{1}$$

$$M = \bar{M}\left(\frac{P_m}{\bar{P}_m}\right)^{\sigma_m} \tag{2}$$

where Y is the value of domestic production, M is the value of imports, P is the corresponding price, and bars ($\bar{\ }$) denote the benchmark value of a variable. Domestic and foreign demand are specified similarly to production as:

$$D = \bar{D}\left(\frac{P_c}{\bar{P}_c}\right)^{\sigma_{dD}} \tag{3}$$

$$X = \bar{X}\left(\frac{P_y}{\bar{P}_y}\right)^{\sigma_{fD}} \tag{4}$$

where D is total domestic demand and X is total export demand. We specified total domestic consumption as an aggregate of domestic- and foreign-produced goods using the calibrated share form of the CES function as:

$$dD = \theta \mathrm{D}\left(\frac{P_c}{\mathrm{p_y}}\right)^{\sigma_C} \tag{5}$$

$$fD = (1-\theta)\mathrm{D}\left(\frac{P_c}{\mathrm{p_m}}\right)^{\sigma_C} \tag{6}$$

where dD is domestic consumer demand for domestic goods, and fD is domestic consumer demand for foreign goods, and:

$$\theta = \frac{p_y \overline{dD}}{p_y \overline{D} + p_m \overline{fD}} \tag{7}$$

$$p_c = \bar{p}_c \left(\theta \left(\frac{p_y}{\bar{p}_y} \right)^{(1-\sigma_C)} + (1-\theta) \left(\frac{p_m}{\bar{p}_m} \right)^{(1-\sigma_C)} \right)^{\frac{1}{1-\sigma_C}} \tag{8}$$

The final conditions for the model require market clearance (*i.e.*, that supply equal demand in the domestic and foreign markets for the chemical). We specified this requirement as:

$$0 = Y - X - dD \tag{9}$$

$$0 = M - fD \tag{10}$$

These nine equations (excluding the θ parameter definition in equation 9) form the basis of our model with the six quantity (Y, M, D, X, dD, fD) and three price (p_y, p_m, p_c) variables, which makes a square system of equations that we can implement in a constrained nonlinear system (CNS) mathematical program in the GAMS software language using a constrained optimization solver.

5.3.1.5 SOCMI Model Simulations and Results

For each of the seven chemicals in this analysis, we implemented five counterfactual shocks to the model to simulate new market outcomes. To implement counterfactual cases including increased production costs from regulatory compliance or inflation, we included cost shock parameters in equations (11) and (12) as follows:

$$Y = \bar{Y} \left(\frac{P_y}{(1 + c_y)\bar{P}_y} \right)^{\sigma_y} \tag{11}$$

$$M = \bar{M} \left(\frac{P_m}{(1 + c_f)\bar{P}_m} \right)^{\sigma_m} \tag{12}$$

where the cost parameters, c_y and c_f, are expressed in percentage terms and, when positive, reduce the effective prices received by suppliers.

Our analysis of the economic impact of costs includes three scenarios:

1) compliance costs due to the HON rule,
2) the compliance costs due to the two P&R rules,

3) the total compliance costs due to the three rules.

We also modeled two foreign market inflation scenarios to investigate the impact/interactions of an increased price of natural gas in foreign producing countries:

1) inflation cause by rises in foreign natural gas (NG) prices only—primarily energy inputs. This is referred to as foreign low inflation (INF_LO).

2) inflation cause by rises in foreign NG and natural gas liquid (NGL) prices associated with the product inputs. This is referred to as foreign inflation high (INF_HI).

- Note: We assumed foreign gas prices do not affect domestic production costs.

For the inflation caused by NG and NGL price increases, we applied the average annual spot price increase in German NG prices from 2018 to 2021 ($8.57/mmBtu and $15.91 mm/Btu, respectively[35]) to the price increases due to NG and NGL price changes from the ACS study on the impact of NG and NGL prices on the U.S. chemical manufacturing industry (DeRosa, 2015). The chemicals with benzene as a feedstock—butadiene, styrene, and acetone—do not have any production cost increase associated with increased NG or NGL prices because benzene is a production by-product of other higher value products and does not have a cost change due to NG or NGL prices.

For each of the seven chemicals, we ran a business-as-usual (BAU) benchmark replication (*i.e.,* essentially a baseline model run) and the following five model runs:

- BAU: $c_y = 0\%$ and $c_f = 0\%$ (no compliance costs and no foreign inflation)
- HON: c_{y1} = HON compliance costs only
- PR: c_{y2} = P&R compliance costs only
- CC TOT : $c_{y1} + c_{y2}$ = HON and P&R total compliance.
- INF: c_f = Foreign inflation costs only (no compliance costs)
- CC+INF: $c_{y1} + c_{y2} + c_f$ = HON and P&R compliance costs and foreign inflation costs

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[35] https://ycharts.com/indicators/germany_natural_gas_border_price

Model results for each of the seven chemicals included in the analysis are presented in Tables 5-4 through Table 5-10. The simulated market impacts are consistent with our expectations in that control costs result in higher market prices and lower output and foreign inflation leads to domestic output percentage increases and dampens the impact of the regulation's compliance costs.

- Butadiene shows modest impacts of domestic production, decreasing about 0.20%. Because butadiene is a benzene by-product, there is no impact on foreign production costs due to NG or NGL price changes.
- Styrene and ethylene dichloride see the smallest impacts on domestic production, decreasing less than 0.05%.
- Acrylonitrile sees the largest output drop in response to compliance costs (0.57%) because of its smaller market size and relatively higher P&R compliance costs. Acrylonitrile also sees a high percentage drop in imports from higher foreign NG prices because of its high sensitivity to NGL prices.
- Acetone is the only product that does not see (at our significance level) a drop in production or an increase in price due to the compliance costs because of its very low relative compliance cost increase (only 0.17% of production costs).
- Ethylene glycol has a production decrease of about 0.5% with compliance costs. However, it sees a net increase in production of about 0.25% with the foreign NG prices increase.
- Ethylene oxide faces the highest compliance costs for chemical products affected by this proposal due to the expected use of large add-on control technologies such as thermal oxidizers for compliance with the HON and P&R I requirements. It only sees a modest decrease in domestic production, however, because of its large domestic market and very low imports. In particular, there have been almost no ethylene oxide imports to the United States in the past 5 years.

Table 5-4: Butadiene Results

	BAU	HON	PR	CC_TOT	INF	CC+INF
Quantities						
Output	1,218	1,217	1,217	1,216	1,218	1,216
		−0.11%	−0.09%	−0.20%	0.00%	−0.20%
Exports	46	46	46	46	46	46
		−0.05%	−0.04%	−0.08%	0.00%	−0.08%
Imports	391	392	392	392	391	392
		0.12%	0.09%	0.21%	0.00%	0.21%
Demand	1,563	1,563	1,563	1,562	1,563	1,562
		−0.06%	−0.04%	−0.10%	0.00%	−0.10%
Prices ($000/tonne)						
Domestic	1.22	1.22	1.22	1.22	1.22	1.22
		0.16%	0.08%	0.25%	0.00%	0.25%
Consumption	1.22	1.22	1.22	1.22	1.22	1.22
		0.16%	0.08%	0.25%	0.00%	0.25%
Import	1.22	1.22	1.22	1.23	1.22	1.23
		0.25%	0.16%	0.41%	0.00%	0.41%

Table 5-5: Styrene Simulation Results

	BAU	HON	PR	CC_TOT	INF	CC+INF
Quantities						
Output	3,659	3,658	3,659	3,657	3,659	3,657
		−0.04%	−0.02%	−0.06%	0.00%	−0.06%
Exports	1,100	1,099	1,100	1,099	1,100	1,099
		−0.04%	−0.01%	−0.05%	0.00%	−0.05%
Imports	212	212	212	212	212	212
		0.08%	0.03%	0.11%	0.00%	0.11%
Demand	2,771	2,770	2,771	2,770	2,771	2,770
		−0.04%	−0.02%	−0.05%	0.00%	−0.05%
Prices ($000/tonne)						
Domestic	1.84	1.84	1.84	1.84	1.84	1.84
		0.11%	0.05%	0.11%	0.00%	0.11%
Consumption	1.84	1.84	1.84	1.84	1.84	1.84
		0.11%	0.05%	0.11%	0.00%	0.11%
Import	1.84	1.84	1.84	1.85	1.84	1.85
		0.16%	0.05%	0.22%	0.00%	0.22%

Table 5-6: Acrylonitrile Simulation Results

	BAU	HON	PR	CC_TOT	INF	CC+INF
Quantities						
Output	848	844	848	844	850	845
		−0.54%	−0.04%	−0.57%	0.18%	−0.39%
Exports	529	527	529	526	528	525
		−0.52%	−0.03%	−0.55%	−0.34%	−0.90%
Imports	9	9	9	9	6	6
		0.52%	0.03%	0.57%	−38.34%	−38.00%
Demand	328	326	328	326	328	326
		−0.53%	−0.04%	−0.57%	0.07%	−0.50%
Prices ($000/tonne)						
Domestic	1.04	1.05	1.04	1.05	1.04	1.05
		0.48%	0.00%	0.58%	0.29%	0.87%
Consumption	1.04	1.05	1.04	1.05	1.04	1.05
		0.48%	0.00%	0.58%	−0.10%	0.48%
Import	1.04	1.05	1.04	1.05	0.85	0.86
		0.96%	0.10%	1.06%	−18.37%	−17.50%

Table 5-7: Acetone Simulation Results

	BAU	HON	PR	CC_TOT	CC+INF_LO	CC+INF_HI
Quantities						
Output	1,515	1,515	1,515	1,515	1,515	1,515
		0.00%	0.00%	0.00%	0.00%	0.00%
Exports	42	42	42	42	42	42
		0.00%	0.00%	0.00%	0.00%	0.00%
Imports	84	84	84	84	84	84
		0.00%	0.00%	0.00%	0.00%	0.00%
Demand	1,557	1,557	1,557	1,557	1,557	1,557
		0.00%	0.00%	0.00%	0.00%	0.00%
Prices ($000/tonne)						
Domestic	1.84	1.84	1.84	1.84	1.84	1.84
		0.00%	0.00%	0.00%	0.00%	0.00%
Consumption	1.84	1.84	1.84	1.84	1.84	1.84
		0.00%	0.00%	0.00%	0.00%	0.00%
Import	1.84	1.84	1.84	1.84	1.84	1.84
		0.00%	0.00%	0.00%	0.00%	0.00%

Table 5-8: Ethylene Dichloride Simulation Results

	BAU	HON	PR	CC_TOT	INF	CC+INF
Quantities						
Output	9,731	9,729	9,731	9,729	9,731	9,729
		−0.03%	0.00%	−0.03%	0.00%	−0.03%
Exports	727	727	727	727	727	727
		−0.03%	0.00%	−0.03%	0.00%	−0.03%
Imports	0	0	0	0	0	0
		0.21%	0.00%	0.21%	−8.00%	−8.00%
Demand	9,004	9,002	9,004	9,002	9,004	9,002
		−0.03%	0.00%	−0.03%	0.00%	−0.03%
Prices ($000/tonne)						
Domestic	0.72	0.72	0.72	0.72	0.72	0.72
		0.14%	0.00%	0.14%	0.00%	0.14%
Consumption	0.72	0.72	0.72	0.72	0.72	0.72
		0.14%	0.00%	0.14%	0.00%	0.14%
Import	0.72	0.72	0.72	0.72	0.70	0.70
		0.14%	0.00%	0.14%	−3.46%	−3.32%

Table 5-9: Ethylene Glycol Simulation Results

	BAU	HON	PR	CC_TOT	INF	CC+INF
Quantities						
Output	1,578	1,571	1,578	1,571	1,589	1,582
		−0.43%	0.00%	−0.43%	0.67%	0.26%
Exports	1,269	1,266	1,269	1,266	1,263	1,260
		−0.23%	0.00%	−0.23%	−0.47%	−0.71%
Imports	237	239	237	239	222	223
		0.79%	0.00%	0.79%	−6.44%	−5.73%
Demand	546	544	546	544	548	546
		−0.37%	0.00%	−0.37%	0.31%	-0.05%
Prices ($000/tonne)						
Domestic	1.04	1.04	1.04	1.04	1.05	1.06
		0.58%	0.00%	0.58%	1.25%	1.93%
Consumption	1.04	1.05	1.04	1.05	1.03	1.04
		0.96%	0.00%	0.96%	-0.77%	0.10%
Import	1.04	1.05	1.04	1.05	1.00	1.01
		1.45%	0.00%	1.45%	−3.66%	−2.31%

Table 5-10: Ethylene Oxide Simulation Results

	BAU	HON	PR	CC_TOT	INF	CC+INF
Quantities						
Output	2,400	2,395	2,400	2,395	2,400	2,395
		−0.23%	0.00%	−0.23%	0.00%	−0.23%
Exports	1	1	1	1	1	1
		−0.22%	0.00%	−0.22%	0.00%	−0.22%
Imports	0	0	0	0	0	0
		0.00%	0.00%	0.00%	0.00%	0.00%
Demand	2,399	2,394	2,399	2,394	2,399	2,394
		−0.23%	0.00%	−0.23%	0.00%	−0.23%
Prices ($000/tonne)						
Domestic	1.49	1.50	1.49	1.50	1.49	1.50
		0.61%	0.00%	0.61%	0.00%	0.61%
Consumption	1.49	1.50	1.49	1.50	1.49	1.50
		0.61%	0.00%	0.61%	0.00%	0.61%
Import	1.49	1.50	1.49	1.50	1.46	1.47
		0.94%	0.00%	0.94%	−1.75%	−0.87%

5.4 Small Business Impacts Analysis

For the proposed rule, the EPA performed a small entity screening analysis for impacts on all affected facilities by comparing compliance costs to historic revenues at the ultimate parent company level. This is known as the cost-to-revenue or cost-to-sales test, or the “sales test.” The sales test is an impact methodology the EPA employs in analyzing entity impacts as opposed to a “profits test,” in which annualized compliance costs are calculated as a share of profits. The sales test is frequently used because revenues or sales data are commonly available for entities impacted by the EPA regulations, and profits data normally made available are often not the true profit earned by firms because of accounting and tax considerations. Also, the use of a sales test for estimating small business impacts for a rulemaking is consistent with guidance offered by the EPA on compliance with the Regulatory Flexibility Act (RFA)[36] and is consistent with guidance published by the U.S. Small Business Administration’s (SBA) Office of Advocacy that suggests that cost as a percentage of total revenues is a metric for evaluating cost increases on small entities in relation to increases on large entities (SBA, 2017).

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[36] The RFA compliance guidance to the EPA rule writers can be found at <https://www.epa.gov/sites/production/files/2015-06/documents/guidance-regflexact.pdf >

For purposes of assessing the impacts of this action on small entities, a small entity is defined as: (1) a small business as defined by the Small Business Administration's (SBA) regulations at 13 CFR 121.201; (2) a small governmental jurisdiction that is a government of a city, county, town, school district or special district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise that is independently owned and operated and is not dominant in its field. Businesses in the Gasoline Distribution source category predominately have NAICS codes 325199 (All Other Basic Organic Chemical Manufacturing). For the SBA small business size standard definition for each NAICS classification, see below in Table 5-11.

Table 5-11. SBA Size Standards by NAICS Code

NAICS Codes	NAICS U.S. Industry Title	Size Standards (million$ of annual sales/revenues)	Size Standards (Number of employees)
325110	Petrochemical Manufacturing		1,000
325120	Industrial Gas Manufacturing		1,000
325130	Synthetic Dye and Pigment Manufacturing		1,000
325180	Other Basic Inorganic Chemical Manufacturing		1,000
325194	Cyclic Crude, Intermediate, and Gum and Wood Chemical Manufacturing		1,250
325199	All Other Basic Organic Chemical Manufacturing		1,250
325211	Plastics Material and Resin Manufacturing		1,250
325212	Synthetic Rubber Manufacturing		1,000
325220	Artificial and Synthetic Fibers and Filaments Manufacturing		1,000
325311	Nitrogenous Fertilizer Manufacturing		1,000
325320	Pesticide and Other Agricultural Chemical Manufacturing		1,000
325412	Pharmaceutical Preparation Manufacturing		1,250
325620	Toilet Preparation Manufacturing		1,250
325920	Explosives Manufacturing		750
325998	All Other Miscellaneous Chemical Product and Preparation Manufacturing		500

EPA constructed a facility list for the HON and P&R Group I and II source categories. For information on how this list was constructed, see Section 2. The initial facility lists consisted of 207 HON facilities, 19 P&R I facilities (and 10 of the P&R I facilities are collocated with HON processes), and 5 P&R II facilities (and 3 of the P&R II facilities are collocated with HON processes). However, revised counts of active and unique facilities reduced the size of these lists.

EPA identified the ultimate parent company along with revenue and employment information for facilities using D&B Hoover's database. In total, EPA identified 100 ultimate parent companies as owners of the 214 facilities, of which ten of these ultimate parent companies were identified as small entities (counts of parent companies do not sum over rules due to some companies owning facilities subject to multiple rules). These companies, including the small entities, operate in the SOCMI industry, which is marginally competitive as a whole as mentioned in Chapter 2 of this RIA. Summary statistics for these ultimate parent companies are in Table 5- below.

Table 5-12. Summary Statistics of Potentially Affected Entities

Rule	Size	No. of Ultimate Parent Companies	Number of Facilities	Mean Revenue (million 2021$)	Median Revenue (million 2021$)
HON	Small	10	11	$252	$72.1
	Not Small	88	192	$22,600	$5,160
P&R I	Small	1	2	$290	$290
	Not Small	11	16	$40,900	$8,940
P&R II	Small	0	0	-	-
	Not Small	4	5	$78,900	$22,900
Rules Combined	Small	10	11	$252	$72.1
	Not Small	90	203	$22,400	$5,160

Note: Some facilities are affected by more than one rule and therefore, to avoid double counting, "Rules Combined" will not equal the sum of facilities noted in individual rules.

5.4.1 Screening Analysis

Using the facility list discussed in the above section, EPA conducted cost-to-sales analysis for the proposed action to screen small entities for potentially significant impacts. We present results specifically for each of the HON, P&R I and P&R II proposals, and a total estimate for all of these three rules. We are unable to provide an estimate of small entity impacts for the NSPS in this proposed action due to an inability to link impacts to specific known facilities and ultimate parent owners. While a sales test can provide some insight as to the economic impact of an action such as this one, it assumes that the impacts of a rule are solely incident on a directly affected firm (therefore, no impact to consumers of the affected product), or solely incident on consumers of output directly affected by this action (therefore, no impact to companies that are producers of the affected product). Thus, an analysis such as this one is best viewed as providing insight on the polar opposites of economic impacts: maximum impact to either directly affected companies with no impact on their consumers, or vice versa. A sales test analysis does not consider shifts in supply and demand curves to reflect intermediate economic outcomes. For a partial equilibrium analysis of the economic impacts of this action that attempts to parse impacts on consumers relative to producers, see section 5.2.

The results of this analysis for the proposed options are presented below. Table 5-13 shows the distribution of average costs for ultimate parent companies by proposed rule. Tables-8 and 9 below show the distribution of cost-to-sale ratios (CSRs) by rule and the percentage of CSRs clearing 1 percent and 3 percent for each rule. We present the results both with costs including product recovery and without product recovery. The results are virtually identical regardless of whether or not product recovery is included.

Table 5-13: Distribution of Estimated Compliance Costs by Rule and Size for Proposed Options ($2021)[a]

Rule	Size	No. of Firms	Average Cost with Product Recovery	Average Cost without Product Recovery
HON	Small	10	$261,000	$265,000
	Not Small	88	$854,000	$850,000
P&R I	Small	1	$43,900	$43,900
	Not Small	11	$921,000	$922,000
P&R II	Small	0	-	-
	Not Small	4	$333,000	$333,000
Rules Combined	Small	10	$227,000	$231,000
	Not Small	90	$843,000	$847,000

[a] There are some firms, including one small firm, that are impacted by more than one proposed rule. This explains why the totals of combined impacted firms are less than the straight summation across the proposed rules.

Table 5-14: Compliance Cost-to-Sales Ratio Distributions for Small Entities, Proposed Options[a]

Rule			With Product Recovery Included		Without Product Recovery Included	
			Mean CSR	Maximum CSR	Mean CSR	Maximum CSR
HON	No. of Small Entities	10	0.427%	1.26%	0.459%	1.40%
P&R I		1	0.030%	0.030%	0.030%	0.030%
P&R II		0	-	-	-	-
All	No. of Small Entities	10	0.431%	1.26%	0.462%	1.40%

[a] There is one small firm that is impacted by more than one proposed rule. This explains why the totals of combined impacted firms are less than the straight summation across the proposed rules.

Table 5-15: Compliance Cost-to-Sales Ratio Thresholds for Small Entities - Proposed Options[a]

Rule		With Product Recovery Included		Without Product Recovery Included	
		No. of Small Entities	% of Small Entities	No. of Small Entities	% of Small Entities
HON	No. of Small Entities	10	100%	10	100%
	Greater than 1%	2	20%	2	20%
	Greater than 3%	0	0.0%	0	0.0%
P&R I	No. of Small Entities	1	100%	1	100%
	Greater than 1%	0	0.0%	0	0.0%
	Greater than 3%	0	0.0%	0	0.0%
P&R II	No. of Small Entities	0	-	0	-
	Greater than 1%	-	-	-	-
	Greater than 3%	-	-	-	-
All	No. of Small Entities	10	100%	10	100%
	Greater than 1%	2	20%	2	20%
	Greater than 3%	0	0.0%	0	0.0%

[a] There is one small firm, that is impacted by more than one proposed rule. This explains why the totals of combined impacted firms are less than the straight summation across the proposed rules.

Given the relatively low average CSR for small entities (both with and without product recovery), as well as there being only two small entities with a CSR of at least 1 percent and no small entities with a CSR of at least 3 percent for the proposed HON amendments, we conclude that it is unlikely that the proposed changes to the HON would have a significant impact on a substantial number of small entities (SISNOSE), and therefore we certify that there is no SISNOSE for this proposal Given that there are no small entities with a CSR of at least 1 percent for either the P&R I or P&R II proposals, we conclude that we can certify no SISNOSE for either of these proposed rules.

5.5 Employment Impact Analysis

This section presents a qualitative overview of the various ways that environmental regulation can affect employment. Employment impacts of environmental regulations are generally composed of a mix of potential declines and gains in different areas of the economy over time. Regulatory employment impacts can vary across occupations, regions, and industries; by labor and product demand and supply elasticities; and in response to other labor market conditions. Isolating such impacts is a challenge, as they are difficult to disentangle from employment impacts caused by a wide variety of ongoing, concurrent economic changes. The EPA continues to explore the relevant theoretical and empirical literature and to seek public comments in order to ensure that the way the EPA characterizes the employment effects of its regulations is reasonable and informative.

Environmental regulation "typically affects the distribution of employment among industries rather than the general employment level" (Arrow, et al., 1996). Even if impacts are small after long-run market adjustments to full employment, many regulatory actions have transitional effects in the short run (Office of Management and Budget, 2015). These movements of workers in and out of jobs in response to environmental regulation are potentially important and of interest to policymakers. Transitional job losses have consequences for workers that operate in declining industries or occupations, have limited capacity to migrate, or reside in communities or regions with high unemployment rates.

6 COMPARISION OF COSTS AND BENEFITS

In this chapter, we present a comparison of the benefits and costs of this proposed action. We present benefits and costs for each proposed rule and their more and less stringent alternatives, except we group the impacts of the IIIa, NNNa, and RRRa NSPS proposals together for presentational clarity and consistent with the presentation of impacts for these three NSPS in the preamble for this proposed action. As explained in the previous chapters, all costs and benefits outlined in this RIA are estimated as the change from the baseline, which reflects the current business practice for the affected sources as mentioned in Chapter 1, particularly with regard to emissions from flares. As stated earlier in this RIA, there is no monetized estimate of the benefits for the HAP emission reductions expected to occur as a result of this proposed action. We do present monetized estimates for other impacts of this action, such as benefits from both short- and long-term reduced exposure to ozone caused by VOC emissions reductions and benefits from decreases in CH_4 emissions and disbenefits from increases in CO_2 and N_2O emissions.

6.1 Results

As part of fulfilling analytical guidance with respect to E.O. 12866, EPA presents estimates of the present value (PV) of the benefits and costs over the period 2024 to 2038. To calculate the PV of the social net benefits of the proposed action, annual benefits and costs are in 2021 dollars and are discounted to 2023 at 3 percent and 7 percent discount rates as directed by OMB's Circular A-4. The EPA also presents the equivalent annualized value (EAV), which represents a flow of constant annual values that would yield a sum equivalent to the PV. The EAV represents the value of a typical cost or benefit for each year of the analysis, consistent with the estimate of the PV, in contrast to year-specific estimates.

The presentation of impacts in this chapter includes those for more and less stringent options to those for the proposal as a whole (that is, across all proposed rules). The more stringent option is the same as the proposal except that tighter controls for HON process vents and storage vessels, and also such controls on P&R I process vents (or PV, when discussing types of affected sources) and storage vessels (SV), are included. The tighter process vent controls in the more stringent option are defined as option PV2 in Table 3-3 of this RIA, and the tighter storage vessels controls are defined as option SV3 in Table 3-2 of this RIA. The less stringent option is the same as the proposal except that weaker controls for storage vessels defined as option SV1 in Table 3-2 of this RIA are included. The less stringent option does not include any other differences in options from the proposal. Thus, the differences in stringency for analyses in the RIA reflect different stringencies primarily in the proposed HON options. Since the differences in stringency occur only for options considered under the proposed HON amendments, we present impacts below for the proposed HON and cumulative. More and less stringent options were not available for the other proposed rules.

Tables 6-1 through 6-3 presents a summary of the monetized benefits, compliance costs, and net benefits (including climate disbenefits) of the proposed HON, proposed P&R I, and cumulatively, and the more and less stringent alternatives for in terms of present value (PV) and equivalent annualized value (EAV). Tables presenting benefits list both figures, with short-term benefits listed first.

Table 6-1: Summary of Monetized Benefits, Compliance Costs, and Net Benefits PV/EAV for HON, 2024-2038 (million 2021$, discounted to 2023)

	Proposal		**Less Stringent Alternative**		**More Stringent Alternative**	
3%	PV	EAV	PV	EAV	PV	EAV
Monetized Health Benefits	$78 and $690	$6.5 and $58	$77 and $690	$6.5 and $58	$79 and $706	$7 and $58
Climate Disbenefits (3%)	(25.4)		(25.4)	(2.1)	(25.4)	(2.1)
Net Compliance Costs	1,385	116	1,381	115	1,440	120
Compliance Costs	1,393	117	1,389	116	1,449	121
Value of Product Recovery	8	1	8	1	9	1
Net Benefits	$(1,280) and $(670)	$(107) and $(56)	(1,278) and $(666)	$(106) and $(55)	$(1,336) and $(709)	$(111) and $(60)
7%						
Monetized Health Benefits	$53 and $470	$5.8 and $51	$53 and $470	$6.5 and $58	$54 and $476	$6.5 and $59
Climate Disbenefits (3%)	(25.4)	(2.1)	(25.4)	(2.1)	(25.4)	(2.1)
Net Compliance Costs	922	101	918	102	959	105
Compliance Costs	927	102	923	103	965	106
Value of Product Recovery	5	0.8	5	1	6	1
Net Benefits	$(844) and $(427)	$(93) and $(48)	$(840) and $(423)	$(93) and $(62)	$(880) and $(458)	$(96) and $(44)

Note: Monetized benefits (incorporating disbenefits) include those related to public health and climate. Monetized air quality related health benefits include ozone related health benefits associated with reductions in VOC emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates. Benefits from HAP reductions and VOC reductions outside of the ozone season remain unmonetized and are thus not reflected in the table. The unmonetized effects also include disbenefits resulting from a secondary increase in CO emissions. Monetized climate benefits and disbenefits are based on changes (increases) in CO_2 and N_2O emissions and decreases in CH_4 emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC-GHG) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the benefits and disbenefits associated with the model average SC-GHG at a 3 percent discount rate, but the Agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits and disbenefits calculated using all four SC-GHG estimates; please see Table 4-11 for the full range of SC-GHG estimates. As discussed in Chapter 4, a consideration of climate disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. The costs presented in this table are 2024 annual estimates. Net compliance costs are the compliance costs minus the value of product recovery from compliance with the rule. Hence, net compliance costs are negative if the value of product recovery exceeds the compliance costs. Parentheses around a number denotes that is has a negative value. Negative climate disbenefits are a positive value. Rows may not appear to add correctly due to rounding.

Table 6-2: Summary of Monetized Benefits, Compliance Costs, and Net Benefits PV/EAV for P&R I, 2024-2038 (million 2021$, discounted to 2023)

	Proposal		**Less Stringent Alternative**		**More Stringent Alternative**	
3%	PV	EAV	PV	EAV	PV	EAV
Health Benefits	$2.6 and $23	$0.22 and $1.9	$2.6 and $23	$0.22 and $1.9	$4.0 and $36	$0.34 and $3.0
Climate Disbenefits (3%)	40.5	3.4	40.5	3.4	40.5	3.4
Net Compliance Costs	121	10	121	10	130	11
Compliance Costs	122	10.2	122	10.2	131.5	11.4
Value of Product Recovery	1	0.2	1	0.2	1.5	0.4
Net Benefits	$(158) and $(138)	$(13) and $(11)	$(158) and $(138)	$(13) and $(11)	$(166) and $(134)	$(14) and $(11)
7%						
Health Benefits	$1.8 and $16	$0.19 and $1.7	$1.8 and $16	$0.19 and $1.7	$2.7 and $24	$0.30 and $2.7
Climate Disbenefits (3%)	40.5	3.4	40.5	3.4	40.5	3.4
Net Compliance Costs	78	8.6	78	8.6	84	9.1
Compliance Costs	79	8.7	79	8.7	85	9.2
Value of Product Recovery	1	0.1	1	0.1	1	0.1
Net Benefits	$(116) and $(103)	$(12) and $(10)	$(116) and $(103)	$(12) and $(10)	$(121) and $(100)	$(12) and $(10)

Note: Monetized benefits (incorporating disbenefits) include those related to public health and climate. Monetized air quality related health benefits include ozone related health benefits associated with reductions in VOC emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates. Benefits from HAP reductions and VOC reductions outside of the ozone season remain unmonetized and are thus not reflected in the table. The unmonetized effects also include disbenefits resulting from a secondary increase in CO emissions. Monetized climate benefits and disbenefits are based on changes (increases) in CO_2 and N_2O emissions and decreases in CH_4 emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC-GHG) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the benefits and disbenefits (and net benefits) associated with the model average SC-GHG at a 3 percent discount rate, but the Agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits and disbenefits calculated using all four SC-GHG estimates; please see Table 4-11 for the full range of SC-GHG estimates. As discussed in Chapter 4, a consideration of climate benefits and disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. The costs presented in this table are 2024 annual estimates. Net compliance costs are the compliance costs minus the value of product recovery from compliance with the rule. Hence, net compliance costs are negative if the value of product recovery exceeds the compliance costs. Rows may not appear to add correctly due to rounding. A number in parentheses denotes a negative value. Negative climate disbenefits are a positive value.

Table 6-3: Summary of Monetized Benefits, Compliance Costs, and Net Benefits PV/EAV for All Rules, 2024-2038 (million 2021$, discounted to 2023)

	Proposal		**Less Stringent Alternative**		**More Stringent Alternative**	
3%	PV	EAV	PV	EAV	PV	EAV
Health Benefits	$81 and $730	$6.8 and $61	$81 and $729	$6.8 and $60	$85 and $765	$7.0 and $63
Climate Disbenefits (3%)	8.2	0.7	8.2	0.7	8.2	0.7
Net Compliance Costs	1,579	132	1,552	130	1,604	134
Compliance Costs	1,590	133.4	1,563	131.4	1,616	135.5
Value of Product Recovery	11	1.4	11	1.4	12	1.5
Net Benefits	$(1,506) and $(857)	$(126) and $(72)	$(1,479) and $(831)	$(124) and $(71)	$(1,527) and $(847)	$(128) and $(72)
7%						
Health Benefits	$56 and $490	$6.1 and $54	$55 and $489	$6.1 and $54	$58 and $516	$6.3 and $56
Climate Disbenefits (3%)	8.2	0.7	8.2	0.7	8.2	0.7
Net Compliance Costs	1,052	121	1,034	119	1,069	123
Compliance Costs	1,060	122	1,041	120.2	*1,077*	*124.3*
Value of Product Recovery	7.7	1.1	6.5	1.2	*8*	*1.3*
Net Benefits	$(1,100) and $(562)	$(110) and (63)	$(1,081) and $(553)	$(124) and $(66)	$(1,019) and $(551)	$(117) and $(68)
Nonmonetized Benefits	6,053 tons/year of HAP Health effects of reduced exposure to ethylene oxide, chloroprene, benzene, 1,3-butadiene, vinyl chloride, ethylene dichloride, chlorine, maleic anhydride and acrolein					

Note: Monetized benefits (incorporating disbenefits) include those related to public health and climate. Monetized air quality related health benefits include ozone related health benefits associated with reductions in VOC emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates. Benefits from HAP reductions and VOC reductions outside of the ozone season remain unmonetized and are thus not reflected in the table. The unmonetized effects also include disbenefits resulting from a secondary increase in CO emissions. Monetized climate benefits and disbenefits are based on changes (increases) in CO_2 and N_2O emissions and changes (decreases) in CH_4 emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC-GHG) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the benefits and disbenefits (and the net benefits) associated with the model average SC-GHG at a 3 percent discount rate, but the Agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits and disbenefits calculated using all four SC-GHG estimates; please see Table 4-11 for the full range of SC-GHG estimates. As discussed in Chapter 4, a consideration of climate disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. The costs presented in this table are 2024 annual estimates. Net compliance costs are the compliance costs minus the value of product recovery from compliance with the rule. Hence, net compliance costs are negative if the value of product recovery exceeds the compliance costs. A number in parentheses denotes a negative value. Negative climate disbenefits are a positive value. Rows may not appear to add correctly due to rounding.

Given these results, the EPA expects that implementation of the proposed HON, based solely on an economic efficiency criterion, should provide society with a relatively potential net gain in welfare, notwithstanding the expansive set of health and environmental benefits and other impacts we were unable to quantify such as monetization of benefits from VOC emission reductions occurring outside of the ozone season (the months of October-April). The same holds true for the proposed P&R I and II NESHAP and for all proposed amendments (including the NSPS) considered cumulatively. Further quantification of directly emitted VOC and HAP would increase the estimated net benefits of each proposed action and cumulatively.

6.2 Uncertainties and Limitations

Throughout the RIA, we considered a number of sources of uncertainty, both quantitatively and qualitatively, regarding the benefits, and costs of the proposed amendments. We summarize the key elements of our discussions of uncertainty here:

Projection methods and assumptions: Over time, more facilities are newly established or modified in each year, and to the extent the facilities remain in operation in future years, the total number of facilities subject to the action could change. We assume 100 percent compliance as these proposed rules and existing rules are implemented, starting from when the source becomes affected. If sources do not comply with these rules, at all or as written, the cost impacts and emission reductions may be overestimated. Additionally, new control technology and approaches may become available in the future at lower cost, and we are unable to predict exactly how industry will comply with the proposed rules in the future.

Years of analysis: In addition, the counts of units projected to be affected by this proposed action are held constant. Given our analytical timeframe of 2024-2038, it is possible that the affected unit counts may change. The years of the cost analysis are 2024, to represent the first-year facilities that the NSPS proposed in this rulemaking will be effective, through 2038, to represent impacts of the action over the life of installed capital equipment, as discussed in Chapter 3. Extending the analysis beyond 2038 would introduce substantial and increasing uncertainties in projected impacts of the proposed regulations.

- **Compliance Costs**: There may be an opportunity cost associated with the installation of environmental controls (for purposes of mitigating the emission of pollutants) that is not reflected in the compliance costs included in Chapter 3. If environmental investment displaces investment in productive capital, the difference between the rate of return on the marginal investment (which is discretionary in nature) displaced by the mandatory environmental investment is a measure of the opportunity cost of the environmental requirement to the regulated entity. To the extent that any opportunity costs are not included in the control costs, the compliance costs presented above for this proposed action may be underestimated.

BPT estimates: As discussed earlier in Chapter 4, all national-average BPT estimates reflect the geographic distribution of the modeled emissions, which may not exactly match the emission reductions that would occur due to the action, and they may not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors for any specific location. Recently, the EPA systematically compared the changes in benefits, and concentrations where available, from its BPT technique and other reduced-form techniques to the changes in benefits and concentrations derived from full-form photochemical model representation of a few different specific emissions scenarios. Reduced form tools are less complex than the full air quality modeling, requiring less agency resources and time. That work, in which we also explore other reduced form models is referred to as the "Reduced Form Tool Evaluation Project" (Project), began in 2017, and the initial results were available at the end of 2018. The Agency's goal was to better understand the suitability of alternative reduced-form air quality modeling techniques for estimating the health impacts of criteria pollutant emissions changes in the EPA's benefit-cost analysis. The EPA continues to work to develop refined reduced-form approaches for estimating benefits. The scenario-specific emission inputs developed for this project are currently available online. The study design and methodology are described in the final report summarizing the results of the project, available at https://www.epa.gov/sites/production/files/2019-11/documents/rft_combined_report_10.31.19_final.pdf.

Non-monetized benefits: Numerous categories of health and welfare, and climate-related benefits are not quantified and monetized in this RIA. These unquantified benefits, including benefits from reductions in emissions of pollutants such as HAP which are to be reduced by this proposed action, are described in detail in Chapter 4 of this RIA and various NAAQS RIAs.

VOC health impacts: In this RIA, we quantify an array of adverse health impacts attributable to emissions of VOC. The Integrated Science Assessment for Particulate Matter ("ISA") (U.S. EPA, 2019) identifies the human health effects associated with ambient particles, which include premature death and a variety of illnesses associated with acute and chronic exposures.

Monetized climate benefits and disbenefits: The EPA considered the uncertainty associated with the interim social cost of carbon (SC-GHG) estimates, which were used to calculate the climate benefits and disbenefits from the increase in CO_2 and N_2O emissions and the decrease in CH_4 emissions projected under the proposed amendments in this rulemaking. Some uncertainties are captured within the analysis, while other areas of uncertainty have not yet been quantified in a way that can be modeled. A full list and discussion of uncertainties in the analysis of monetized climate benefits and disbenefits can be found in Chapter 4 of this RIA.

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